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BREEDING HABITS OF CRAYFISH.

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OF the breeding habits of the European crayfish much is known, but this is not the case with the American species. The easy assumption that the habits here were essentially identical with those there, has been, possibly, one reason why so little has been put on record regarding our American forms. That there are, however, some considerable differences will appear from the following notes made upon that common species *Cambarus affinis* in 1894 and 1900-1903. Though these observations were made upon individuals kept in confinement in the Biological Laboratory, they may, for the most part, be taken as a guide to what is to be expected from field observations, which still remain much to be desired.

Sex ratio.—The specimens used were taken from the Potomac River in Maryland and when attention was given to the ratio of the sexes it was found that one lot in March 15, 1901, contained 26 females and 14 males while another lot, April 20, 1903, contained 39 females and 14 males. While this shows a marked predominance of females over males at those periods and at that locality it is not general, for a lot of eighty of the same species taken in October, 1903, from a pond in Baltimore, con-

tained 41 females and 39 males. Even where the females are more abundant there is no probability of the eggs going without fertilization since it was found that one male unites with several females.

Time of sexual union.—When specimens were taken in February and put into tanks some unions occurred at once while others were deferred till March. When the sexes were kept separate till March 6 and then put into one tank, unions took place March 6, 7, 8, 9, 10 and 11. After that there were occasional unions, especially of the younger and smaller animals, up to April 2. Besides these observed unions in February, March and April it would seem that there is an Autumnal pairing, in place of or in addition to the Spring pairing. Several small specimens reared from eggs laid in the Spring were found to pair early in October of the same year; while at that same time pairs of larger size were taken in a pond in Baltimore. Moreover specimens from Washington, D. C., in 1894, in November, were seen to pair as soon as they were put into a shallow dish.

Description of sexual union.—The union of the sexes in *C. affinis* was first observed in 1894, and briefly described in the *American Naturalist* in 1895. The same phenomena have been repeatedly witnessed in successive years and there is no doubt that in this species of crayfish the sperm is transferred from the male to an external seminal receptacle upon the female where it is stored up till the time that the eggs are laid. There is no copulation or use of intromittent organs such as takes place in the crabs; nor on the other hand is there any such vague attachment of spermatophores as has been described in the European crayfish, *Astacus*.

In captivity the union lasts from two to ten hours and either the male or the female may repeat the process with other individuals.

When a female is put into a dish in which a male has been kept till he is accustomed to it he soon seems aware of the presence of the female and does not act as he does when only males are introduced. The preliminary steps toward union are soon taken. The male advances with ready claws and seizes the female, sometimes gently. The female retreats or, when

seized, often struggles to escape. Despite these struggles the male holding the female with one of his claws fastened to her antenna or to any projecting part of her head eventually succeeds in turning the female over to lie upon her dorsal surface: if there is no struggle the same result follows more directly and methodically. When the female is turned over the male stands over her ventral surface and later transfers the sperm to the receptacle.

When the first seizure is not effective in leading to a ready turning of the female the male exhibits considerable skill and shows something like intelligence in commanding the new circumstances. Two cases were seen in which the male mounted upon the back of the female and seized her claws as is usual after turning the female over, though in this case turning had not been accomplished. In this unusual position the male attempted to adjust the sperm-transferring appendages to the female and then desisted: then the long antennæ of the male were bent down strongly against the dorsal side of the thorax of the female. In one case the exopodites of the third maxilliped were also used in feeling the female. After getting some information, apparently, by the use of these sense organs, the male proceeded to turn the female over and finally continued a normal sperm transfer. In this turning over the male had to deal with the problem of revolving the female through 180° while under his body and starting with his right claw holding her right claw and his left holding her left so that finally his right held her left and his left her right. In accomplishing this feat the male first removed his left claw from the left claws of the female and with it seized her rostrum and adjacent head region: he then turned the female about 90° so that she lay upon her left side while he stood over her right side. Next the right claw released the female's right claws and seized her left claws. He was now able to turn the female through 90° on to her dorsal surface. Then he transferred his left claw from her rostrum to hold all her three right claws. After that the usual union could take place and ten minutes later sperm was transferred and union continued for some hours.

Usually as soon as the male has thrown the female upon her

back he seizes all her clawed legs with his two large claws, holding the three left ones of the female with his one right claw and the three right ones of the female with his left. He then moves forward over the supine female to the position indicated in Fig. 1. From this figure it is evident that the two crayfish are accu-

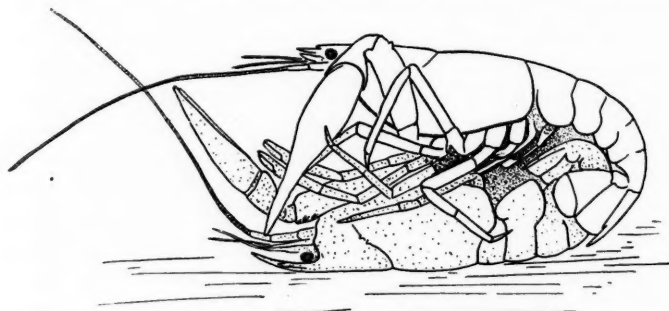


Fig. 1.—Male holding female and with fifth leg supporting abdominal appendages that are about to transfer sperm to the annulus of the female. $\times \frac{1}{2}$ diameter.

ately and closely adjusted to one another; not only does the male hold all the claws of the female, but his abdomen is tightly bent around that of the female which is closely coiled up under the male. While all the five right legs of the female may be seen, there appear to be but four legs of the male's set of five left legs. The base only of the male's fifth leg is shown; posterior to this are the peculiar long male pleopods, or appendages of the first abdominal segment and of the second abdominal segment. These four appendages are elevated at an angle of about 45° and point toward the ventral surface of the thorax of the female, forward and downward. A view of the right side of the pair would, however, show the left fifth leg of the male projecting outward and backward between the fourth and fifth legs of that right side.

The explanation of this peculiar arrangement is found in a habit of the male which seems necessary for the accomplishment of sperm transfer and is a very instructive example of mechanical adjustment amongst several rigid calcified organs. After the male has come forward over the supine female there is a period of ten to twenty minutes of apparent inaction before

the next move which is as follows: the male rises up away from the female, but still holding all her claws, and deliberately passes one of his fifth legs across under his body so that it projects from the other side. When the male again settles down against the female it is found that the pleopods have the position shown in the figure, whereas before this move they had the normal position, being directed forward, horizontally under the thorax of the male.

It is this forced and remarkable position of the fifth leg which secures the necessary elevation of the male pleopods. These pleopods might be compared to the blade of a pen knife half open and tending to shut up into the handle when pressure is exerted against the tip: and as such a blade might be held in position by a pencil placed across between the blade and the handle and held there, so the pleopods are held in position by the crossed leg which lies anterior to them and between them and the thorax of the male. All these parts are firm and rigid and the pleopods articulate only where they hinge to the abdomen. As the male draws himself down with force against the female the pleopods are so held by the above device, that their tips enter the annulus of the female and the pressure so exerted would tend to shut them down into their resting position, but this is opposed by the fifth leg which blocks the pleopods firmly. That there is force exerted by the tips of the pleopods against the annulus was shown in the case of a female that had been reared from the egg in the Laboratory and when put with a male in April of her second year was covered by a dark blackish deposit after wintering. It was soon found that in union with the male the edges of the opening of the annulus had been scraped clean of the dark deposit and stood out conspicuously against the rest of the dark exo-skeleton.

Though the male always uses one of his fifth legs as an apparently necessary secondary sexual organ it is not always the right or the left; males were seen with right and others with left legs so used. Whether the use of right or left is fixed for each male by circumstances or whether it is a matter of chance or whether inherent in the structure of each male was not determined, but a student who kept many crayfish and sought to

determine this point reported to me that one male was seen to use the same leg on one side, in several successive unions with different females.

In one case the fifth leg was seen to project between the third and fourth legs of the opposite side instead of between the fourth and fifth as is the rule. Possibly this may have been in connection with some difference in size between the female and male. Though the two pairing are about the same size there is often considerable difference in length and to secure accurate interadjustment of such rigid bodies with so many protuberances and pairs of appendages is no small problem. To solve it the male at times relaxes his abdomen and moves forward over the female and when finally the tips of the pleopods have been introduced into the annulus the male again envelopes the end of the abdomen of the female and firmly holds it as in the hollow of a hand. The persistent union of the two is made more complete by the use of the hooks found on the legs of the males of this and some other species of *Cambarus*; apparently these fasten the male so that the abdominal pressure exerted down the pleopods against the annulus does not react and push the male upward away from the female. In *C. affinis* there is one of these hooks or spines on the third segment of each third walking leg and the male fastens these two hooks into the base of the fourth legs of the female. In the above figures the male has raised the third left leg so that the hook is free and far from its proper socket. When lowered into place the hook depresses the soft membrane that forms the external aspect of the basal segment and thus a temporary socket is formed. The outer ventral edge of this socket is bounded by the stiff calcified ridges that help form the hinge between the first and second segments and it is against this rigid rim that the spine of the male's leg catches. The use of these male hooks as secondary sexual organs is thus established and we may expect to find that in those species of *cambarus* in which more than one pair of legs are provided with such hooks, that there will be a corresponding increase in complexity of the adjustments of sexual union.

The union of the male and female is now so firm that they cannot be readily separated, and if thrown into actively boiling

water the two may be fixed in almost normal positions and serve to make most excellent museum preparations.¹

Bound together in this way the transfer of sperm from male to female takes place during several hours. Since the crayfish may now be roughly handled or transferred from one dish to another there is little difficulty in observing how the sperm-transfer is effected and a lens may be used without causing the union to cease. The terminal part of the vas deferens of the male, on each side, is found in this period of union to protrude horizontally into the water from the base of each fifth leg as a short, soft, bent tube of translucent appearance. This organ fits exactly into the beginning of the long groove that passes down the first male pleopod, right or left. These pleopods are in fact massive, calcified and rigid tools, each with a deep sinuous groove along it that is seen to lead the sperm from the above ending of the vas deferens down to the tip of the pleopod. The specialized, sharp tips of these organs are inserted into the annulus. The sperm seen to issue from the vas deferens tube glides down the groove of the pleopod to the annulus in the form of long, macaroni-like cords. Microscopic examination of these cords reveals a central axis of real sperm made up almost entirely of the sperm cells and an outer tubular case comparable to soft macaroni. During this transfer of sperm the tip of each pleopod of the second pair is closely applied to the pleopod anterior to it, but no observation was made upon the mode of action of these second pleopods. Each of them has terminal filaments that may well be sensory and also a peculiar, soft, somewhat triangular "spoon" or scoop that fits nicely against the groove of the first pleopod. It would seem that the second pleopods may act to convey sensory impressions and to protect and guide the sperm masses which were found not to go astray but to be in some way retained in the grooves of the first pleopods and forced on into the annulus, probably with the guidance and direction of the second pleopods.

Probably both sides of the body in the male are active at the

¹The same method may be used to advantage for museum specimens of females "in berry" etc., since the coagulation of the liver, etc., lessens the solubility of substances that ordinarily discolor the alcohol.

same time in transferring sperm, but this was not directly observed. During the whole process of union the male is in a state of excitement while the female is quite the reverse, as far as could be judged. The action of the male in turning and adjusting the female is greatly assisted by the state of passivity simulating death that overtakes her soon after being seized by the male. This inertia of the female extends even to the respiratory movements, which seem absent in strong contrast to the condition in the male. The female seems to be dead and the only signs of the continuance of life that were seen were the movements of the eye-stalks in cases where the efforts of the male led to his claws coming against the eyes and, at times, a slight convulsive tremor in the abdomen, possibly connected with sperm transfer. The very small first pair of abdominal appendages which lie often against the annulus and have no probable use unless it be in connection with the phenomena of union, may convey sensory stimuli and occasion the above abdominal contractions. On the other hand the male is in a strongly excited state during the entire period of union: when the struggle and turning have ceased there are still quick vibrations of the anterior maxillipeds and strong currents of water thrown out from the gill chamber as well as the long continued contractions of the limb and abdominal muscles and probably those of the internal male organs. The process terminates when the male moving backward and rising up crosses his fifth leg back again under him into its own side. He then releases the female.

The annulus.—Thus the result of union of male and female is the storing up of sperm within the annulus or sperm receptacle of the female. This is in strong contrast to what has been described as taking place in the European crayfish, *Astacus*, which has no annulus; for French observers state that the male distributes sperm masses, or spermatophores, over large areas of the under side of the female. On the other hand in the American lobster a transfer like that in *Cambarus* doubtless takes place since Bumpus discovered the sperm-containing receptacle upon the female.

The structure which serves in the lobster to hold sperm is,

however, apparently not homologous with the annulus of *Cambarus* but is different in position and construction. Whether there may not be some kind of receptacle in *Astacus*, as some appearances there would suggest, something more like the receptacle of the lobster, is a possibility that needs future consideration. It is well known that the annulus differs in many species of *Cambarus*, and now that we know its use as a sperm receiver we may expect to find some of these specific differences have their uses in the processes of union. The male pleopods are also characteristically and often remarkably different in various species of *Cambarus*, and these differences may find their explanations in their uses with different styles of annuli.

In *C. affinis* the annulus may be described as a calcified region on the ventral side of the thorax between the sterna of the somites bearing the fourth and the fifth legs. The sternum of the former somite is a wide plate, concave across the middle line and rising up at its edges right and left as two high plates that diverge posteriorly and stand close against the bases of the legs. The sternum of the latter somite is a transverse band enlarging at its ends against the right and left fifth legs and bearing at its middle a transversely elongated rounded elevation. All these parts are hard and calcified. The annulus fills all the space between the above sternal plates and thus lies across the ventral line at the interval between the fourth and the fifth legs. It is close against the sternum anterior to it and may be moved slightly as if hung to it by a stiff hinge.

In shape the annulus, Fig. 2, is a transverse and elongated ellipse with pointed ends right and left. It is a calcified plate with two elevations, or hills, of varying size and shape near the middle—one right, the other left. Between



FIG. 2.—Annulus with projecting sperm-plug. $\times 8$ diameters.

these elevations is a longitudinal groove and at the bottom of the posterior part of this groove is a narrow chink into which a fine instrument may be forced. This chink opens posteriorly into a deep groove or valley that runs from right to left across the major part of the annulus. This big groove is just posterior to

the long axis of the annulus and anteriorly it is overhung, somewhat, by the two hills, while posteriorly it is bounded by an elevated lip or transverse ridge that forms the posterior edge of the annulus and sometimes shows a faint crack in it as if made of right and left halves welded together.

Though the hills are right and left the median slope of one extends across the median line of the body of the crayfish so that the chink between the hills is always asymmetrically placed, sometimes on the right and sometimes on the left. In forty-one females, all but two of which were young, probably but four months old, examined in October, only three cases were found in which the chink was on the left side; in the thirty-eight other females it was upon the right side.

In four still younger females, 32-40 mm. long, the annulus was found less well developed and with but slight transverse groove.

Sections of this organ show that the chink opens into a small rounded pouch or sac which as seen from a dorsal view projects upward as a small, curved ridge. Its walls are stiffly calcified cuticle and no opening could be found excepting the external chink above mentioned. This cavity of the annulus serves as the seminal receptacle, but it is only a small, specialized pit in the external cuticle or exo-skeleton.

After sexual union the female shows a white plug of waxy substance projecting from the chink and filling up the transverse groove at that point as indicated in Fig. 2. This plug is necessarily excentric, generally upon the right side, but in some females upon the left side. It is the surplus sperm envelope or macaroni-like case that came down the pleopod groove and was forced into the chink of the annulus. This plug may remain for weeks, but it disappears some time after the eggs are laid. It may thus be used as evidence of foregoing union for a much greater time than the vaginal plug of some rodents can be. Examining the contents of the cavity of the annulus when the plug is in evidence we find it full of a similar compact paste-like material that may be quite hard and has the form of a tubular sheath around a granular mass that proves to be the peculiar sperm cells of the crayfish. The sperm in this sperm receptacle

is in very small amount as compared with the amount produced by one male or with the great mass of eggs to be fertilized, but the actual number of sperm cells is quite large and that they are numerous enough to fertilize all the eggs seems certain though not actually demonstrated. As a fact when females were isolated as soon as union had taken place and kept apart from males till eggs were laid these eggs developed as if fertilized. No sperm was ever seen to be deposited by the male upon other parts of the female than the annulus and if it were not protected as in the annulus it is difficult to see how it could long survive exposure to water which quickly destroys the sperm cells. The laying of eggs, however, may not occur for some weeks after union.

Again, in one case in which the annulus was removed from a female just before laying, the eggs were deposited with normal secretions and habits and though the female was left undisturbed for five days the eggs then appeared shrunken and abnormal, to the naked eye. Twenty-four days later there was only a mass of mouldy dead eggs left on the female. Though there were some cases in which normal females lost most of their eggs by death and fungus yet the above eggs were thought to be all bad from an early date and it is probable they were not fertilized, in the absence of the annulus.

On the whole the evidence seems strongly to favor the view that the sperm received into the annulus in union is the sperm which later fertilizes the eggs. In fact it is possible that sperm taken in antumnal unions may be used for the eggs laid the following spring. Experiments to test this are not yet completed.

Mortality.—The crayfish kept in the laboratory were not fed till after they had laid eggs; then they ate meat, raw and cooked, raw hen's eggs, and pieces of earth worms, as well as Chara and Hydrodictyon. After sexual union many died and it was found that the males died in larger numbers than did the females: thus in one lot seventeen died within two weeks of union in March, and thirteen of those were males and only four females. In several cases the males died within a few hours after union.

Date of laying.—After union there is quite a long period

before the eggs are laid: this period is often some weeks. When about 100 males and females were put together March 6-11 the first eggs were laid March 24th, while other females laid from then on to April 15th, though those laid after the first of April were probably unduly retarded by various artificial influences. That March is the normal time of laying for this species and at the Maryland station on the Potomac whence these specimens came is shown by the fact that 39 females taken there April 20th, 1903, all bore eggs in late stages of development that were almost the same as the various stages then present in the eggs laid in March by the previously captured specimens.

Preparation for laying. — The females tend to secrete them-

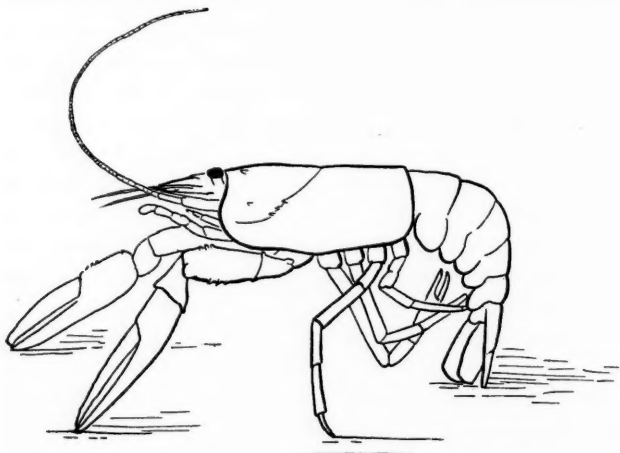


FIG. 3.— Female standing like a tripod and cleaning abdomen with small claws. $\times \frac{1}{2}$.

selves in dark corners and four or five days before laying they are noticeably excitable, an approaching object causes them to raise their claws and to assume the defensive in a much more active way than was previously the case.

These days are also taken up with great and peculiar activity upon the part of the female resulting in a very thorough cleaning of the ventral side of the abdomen. No matter how darkly discolored the exo-skeleton may have become during the winter it is now made white and clean over the under side which then comes to contrast strongly with the remaining dark exterior.

The process of cleaning was observed in a number of cases and always ran the same course. Though the female is now so alert that it is difficult to catch her in the act of cleaning yet the attitude assumed is most noticeable when seen. As indicated in Fig. 3 the body is raised high up from the usual crouching, crawling position and stands like a tripod supported above the bottom of the aquarium upon the two outspread large claws in front and the oddly down-bent abdomen behind. The other legs aid but little in support of the body and are concerned with the cleaning of the abdomen. The fifth legs, and at times the second and third also, were seen to be thrust back under the abdomen and there carefully and patiently used to remove

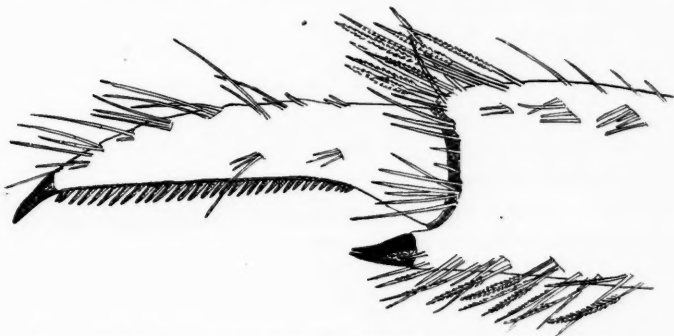


FIG. 4.—Comb and picks on end of fifth leg; used by female to clean abdomen before laying. $\times 20$.

all the dirt from the entire under surface including the pleopods. Even the numerous long, plumose hairs on the pleopods lose their covering of dark "dirt," and the transformation wrought in the appearance of the whole under side of the abdomen is so great that one would suppose the crayfish had cast its shell and wore an entirely new one.

The ends of the fifth legs are shoved against the pleopods and other parts of the abdomen with considerable force but it is only slowly that they accomplish perceptible cleaning. On examining the tips of these legs we find they seem especially well fit for such cleaning work. As indicated in Fig. 4 the terminal segment is like a strong comb, as it has a series of spines

along one free edge. At one of the angles of the penultimate segment there is a group of strong picks that look like the horny tips at the ends of legs. In fact these two picks are born upon a truncated process that suggests a homology with the finger of the chelate legs, that process of the penultimate segment which apposes the last segment to form the claw; and we might regard this fifth leg as having lost, or not yet acquired, a perfect claw. The penultimate segment also bears beautifully serrated hairs, as indicated in the figure, recalling the appearance of some setæ of annelids. That these tufts of serrated hairs may serve as scouring brushes seems not improbable. We would then have a double pick to loosen dirt, a stiff comb and a brush with saw-tooth hairs to accomplish the cleaning.

The fourth leg has the same structure and though it was not seen in use it may well take part in cleaning. The second and third legs bear well developed claws and these were seen slowly plucking at the encrusted abdominal surface. As elsewhere shown¹ these claws are well fitted for cleaning as they can pick off objects and are provided with a long row of flat, serrated plates on each limb of the forceps that should serve excellently in cleaning the pleopods.

Time of laying. — In confinement the crayfish deposited their eggs at night time with few exceptions; only one among thirty-two laid eggs in the day time. Yet it was found possible to force the laying of eggs in the day time by keeping the female every night in barely enough running water to moisten the ventral surface of the body and with no opportunity for the normal submergence. When returned to deeper water in the day time eggs were finally laid, at noon, upon the third day of such treatment.

Laying. — The females were easily disturbed and never laid when under observation so that the actual emission of eggs was not seen but the following facts were observed just before and just after the actual laying. A short time before laying the female is sometimes found lying upon her back waving the abdominal appendages back and forth in a rhythm of about

¹ *Biol. Bull.* Jan. 1904.

one second. The endopodites of the third maxillipeds and the anterior three pairs of legs are sometimes swung back and forth also. Finally a peculiar secretion is passed forth and the eggs are then laid. This secretion is furnished by the "cement glands" of the under side of the female and needs special notice. One of the things that make much for the clean appearance of the under side of the abdomen when the female is about to lay is the presence of large milk-white areas on the basal parts of both endopodites and exopodites of the sixth pair of abdominal appendages, forming very conspicuous white patches when the tail fan is expanded. The other pairs of pleopods are pretty uniformly milk white but the endopodites are more densely white and the glands in their terminal parts are somewhat segmentally arranged. The sternal plates between all six pairs of pleopods also stand out as milk white areas. Anterior to the abdomen the only milky gland areas are the sternal plate of the last somite, the annulus and the edges of the two flaring sternal plates anterior to the annulus. At other times of year these "cement gland" areas seem inactive or at all events inconspicuous. When a portion of one of the milk areas was removed from the tail fan or from any of the smaller pleopods it furnished, under pressure, a milky material which swelled up in water as a clear jelly containing minute spherules as seen under Zeiss 2. D. and as a somewhat milky glair as seen with the naked eye. When first pressed out from a piece of the glandular area the secretion also contains the minute spherules or droplets.

In one case a female was seen to stand with the body raised high above the bottom of the tank and to wave the pleopods back and forth while they gradually became covered with a clear slime or glair. Forty-five minutes later, at 1.15 p. m. the female was lying upon her back and all the eggs had passed out of the oviduct. The general appearance of this female that had just laid is indicated in Fig. 5. Lying upon the back with the limbs stiffly extended and no motion visible the creature seems dead unless the strongly bent abdomen suggest muscular contraction. Passing forward from the widely expanded tail fan is a faint film of slime or glair that

extends to the second legs and neighboring parts. Under this veil a few eggs may be seen not far from the oviduct but the great mass of eggs, several hundred, is concealed by the bent abdomen which encloses them somewhat as a nearly closed hand might a quantity of shot. The actual openings of the oviduct are concealed since the abdomen is bent to its utmost and the tail-fan is carried very far forward over the ventral surface of the thorax. Some slight tremors of globules in the glair near the openings of the oviduct suggested rhythmic contraction of the oviduct, about once a second, even after the

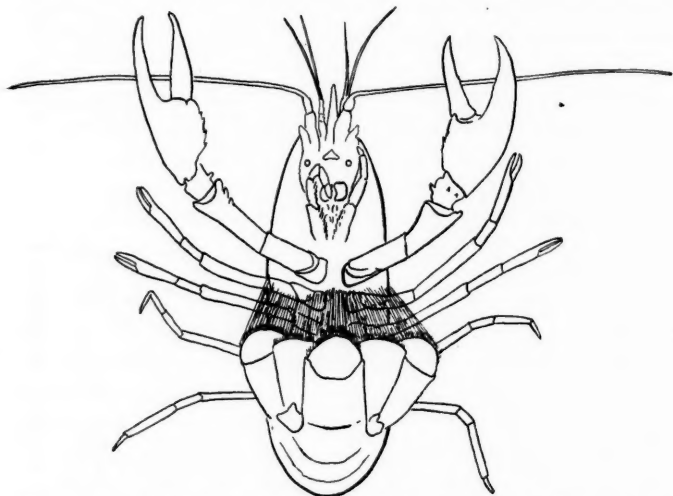


FIG. 5.—Female lying on back with legs held rigid and apron over eggs as they are being laid. $\times \frac{1}{4}$.

eggs had been laid. Gradually the abdomen relaxed somewhat and allowed more of the ventral surface to be seen; while most of the eggs lay in a mass enveloped by the abdomen, some of them still extended forward on to the thorax as a flat layer. After ten minutes there were some slight movements of the legs and then of the second maxillipeds also. Six minutes later the legs moved more actively and a minute later the crayfish turned itself over on to its ventral side, though this was not easily done in a smooth glass dish.

The eggs must have passed out of the oviducts in a short space of time and have been received into the basket formed by the bent up abdomen, a basket full of glair that would protect the eggs from contact with the water. That this glairy substance is the secretion of milk-white cement gland areas seems certain; when the material about the eggs is examined under the microscope it contains droplets like those found in the secretion of the cement gland.

The probable mode of laying may be inferred from the above observations and from the following considerations. If we place a female crayfish upon her back and bend the abdomen forward over the thorax as far as possible we can see that if the eggs were forced out by the contractions of the oviducts they would issue in two streams from the mouths of the oviducts which are on the bases of the antepenultimate legs: they would then emerge into a median triangle-like depression formed by the thoracic sterna and this would form an inclined plane down which the eggs would flow into the basket formed by the abdomen, which is on a lower level. When first seen the eggs were very soft, apparently liquid and most easily deformed and indented yet coming rapidly back to a spheroidal shape, owing, partly at least, to the presence of a thin membrane. At first the eggs were not spherical but pear-shaped or elongated; but when put into hardening liquids they took on a spherical form. When the female is lifted out of the water the soft eggs crowd together and have polyhedral shapes as if liquid, or plastic. In the position assumed by the female it would seem that gravitation acting upon the liquid eggs would bring them into the abdominal basket.

The female that has laid continues to hold the abdomen flexed and the eggs are contained in the basket of glair for some hours. As seen from the side such a female, Fig. 6, seems to have an apron of glair stretching from the second legs and that part of the thorax back to the expanded tail fan and somewhat bellied downward as time goes on. In this condition a remarkable rhythmic habit was observed in several females and regarded as a necessary element in the future success of the eggs. This performance lasts several hours and may be spoken of as:—

Turning.— It consists in a long series of changes in position from the right to the left: the female lies as if dead now on one side and now on the other. After lying a few minutes upon the right the female got back into the ventral position and in a minute or so turned on to the left side, remained there a few minutes and then went back to the ventral position for a minute or two, then to the right side and so on. The striking features in this set of habits are the inert state assumed while lying upon the sides and the great regularity and persistence of the alternating rhythm. The following example will show the details of this process as observed in female XXXII, April 15, 1903, from 1.35—

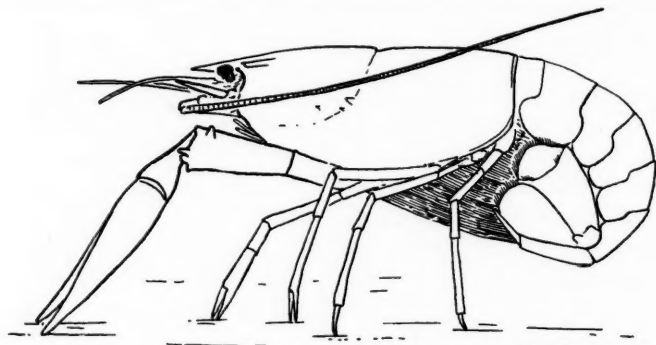


FIG. 6.—Female standing up after laying: apron connecting thorax and bent abdomen.
× 3.

5.50 p. m. As shown in the table this female, as soon as the supine egg-laying position was given up, remained upon her ventral side for three minutes, as in Fig. 6, then turned and lay upon the right side for two minutes, then upon the left side for six minutes, then upon the ventral side for one minute, upon the right side for three minutes and so on.

V₃, R₂, V₀, L₆, V₁, R₃, V₁, L₄, V₂, R_{2½}, V_½, L₄
V₁, R₄, V_{1½}, L_{4½}, V_½, R₃, V_½, L₄, V₁, R₂, V₃, L₆
V₂, R₃, V₁, L₄, V_{1½}, R_{3½}, V₁, L₆, V_{1½}, R₃, V₂, L₄
V_½, R₆, V₀?, L₅, V₁₁×, — — L₃, V₀, R₄, V_½, L_{6½}
V₃,† R_{4½}, V₄, L₄, V₁, R_{4½}, V₁, L_{6½}, V_{2½}, R₅, V₁, L_{6½}
V_{1½}, R_{6½}, V₁, L_{6½}, V₁, R_{7½}, V₁, L₅, V₂, R₇, V_½, L_{5½}
V₂, R₈, V₁, L_{5½}, V₁, R_{7½}, V₁, L_{4½}, V₃, R_{5½}, V —

Observations were discontinued with the animal upon the ventral side at 5.50 p. m. In this long series there is only one break in the rhythm at the point marked x when after 51 minutes of turning in which there were ten alternations from right to left; the female then walked about the dish as if seeking some corner more retired than the one she finally returned to and remained in to make the following ten alternations. This walking away from the corner otherwise so closely kept accounts for the long interval of eleven minutes on the ventral side in place of the usual one of only one or two minutes; to it also may be due the break in the close sequence, the turning upon the left side when the right was the one to be expected; unless indeed we assume the time factor to be so dominant as to cause the female to go over to the left side after eleven minutes because that would have been time enough for, say, a ventral rest of 2 minutes, a right rest of $7\frac{1}{2}$ and a left of $1\frac{1}{2}$ which would bring the period around again to a left rest as next in order. At the point marked † the ventral time is abnormally lengthened as it includes the minute and a half spent by the female in struggling to get her ventral position after accidentally rolling over upon her back from the position on the right.

The result attained by this performance would seem to be the proper fastening of the eggs to the pleopods, without which the eggs would not develop. During this process the female stays in one corner of the dish and except when turning from one position to another lies so still that it might be taken for dead; only rarely were any of the claws reached near to the abdomen and there is no evidence of any manipulation to secure the attachment of the eggs within the abdominal basket. It is well known that ultimately each egg is firmly tied to the hairs of the pleopods (a few also to some sternal hairs) by a strong string continuous with a tough membrane that envelops the egg as a sort of second shell. These strings and cases are gradually formed, and from some of the cement gland secretions no doubt. For twelve hours or more after the eggs are laid they may be easily pulled away from the pleopods as they are stuck only by a soft glair, but later this glair hardens and force is needed to break the strings away from the pleopod hairs. In one case

when the glair, with many eggs, was taken away from the abdomen soon after laying, new glair was formed within a few minutes. When the egg is freshly laid it is covered by a soft slime that may be squeezed off by rolling it under the cover glass; this material looks like the glandular products above described. The abdominal basket seems full of such material and the eggs sinking down through it are seen in masses on right or left sides according to the position of the female. The pleopods hanging down into this mass are probably pouring out over their hairs more and more of the glandular secretion which will finally harden. By turning the female must let all the eggs fall against now the right and now the left pleopods and again when standing, ventral side down, allow the eggs to dangle down in their coatings of slime till strings would, probably, be pulled out above them attaching each to some part of the pleopod.

As there are four to five hundred eggs laid at one time, in one case 631 eggs by count, it is no light problem to get every one well fastened by its own stalk to the abdominal organs that later serve for their protection and aëration.

Any escape and loss of eggs during the turning action is prevented not only by the abdominal basket of slime with its special apron or surface in contact with the water but by the position assumed by the female; when upon her side the legs under the thorax raise it so that gravity would tend to hold the eggs in the abdominal basket; when upon the ventral side the same is generally true since the abdomen is carried lower and the thorax raised.

After the turning has ceased the glair apron is still in evidence and becoming more conspicuous from discoloration and accumulation of dirt. But after some hours it becomes broken by movements of the pleopods and by straightening of the abdomen and is gradually removed. The claws often have masses of glair upon them and perhaps they assist in removing the superfluous mass. Shreds of glair remain attached to the edges of the tail-fan as late as thirty-six hours after the eggs are laid.

Care of eggs. — Very few eggs fail to become fastened to the pleopods in the above process of turning and henceforth the female bears them so fastened till they hatch. When the eggs

were removed and put into dishes of running water they died, except when taken in very late stages with the embryos well formed. The female takes a certain amount of care of the eggs which seems to greatly increase their chances of hatching; as a rule most of the eggs hatch, but in several cases the eggs upon the abdomen became covered by a fungus which bound them all together into one dead, discolored mass. Still the female bore them till long after they should have hatched. That this fungus attacks the eggs in the open was shown by the fact that one of the 39 females taken "in berry" was found to have moulded eggs when received. The female after laying backs into the darkest, most protected corner available and for a long time keeps the abdomen more or less bent down under the eggs which are then protected from dirt; but at times the abdomen is straightened out and the eggs hanging like bunches of grapes from the pleopods are moved back and forth in a manner well calculated to keep them clean and to insure better aëration, Fig. 7.

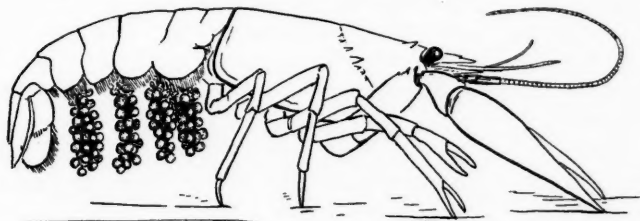


FIG. 7.—Female aërating eggs by raising and straightening abdomen and waving pleopods back and forth. $\times \frac{1}{2}$.

Sometimes also the female may be seen reaching back among the eggs with her smaller claws as if to examine or to clean them. Some of the females died before the young hatched out and this was more often the case amongst the females that had laid in the open and not in the laboratory. If the eggs were left upon the dead female they became overgrown by mould and died; but if taken a week before hatching and put into a McDonald fish-jar they hatched successfully in considerable numbers.

Fertilization. — As most of the eggs hatch and as sections of freshly laid eggs show sperm nuclei there seems no doubt

that the eggs are fertilized and probably the sperm in the annulus is used for that purpose. But, unfortunately, the mode of fertilization or even its actual occurrence has not been made out. The sperm plug may remain visible for a few days after laying but it then disappears. Its appearance also is changed, its end broken, after laying. Examination of the contents of the annulus after laying showed very few sperms. As the eggs are laid they probably pass over the annulus and a relatively small amount of sperm might fertilize all of them if it came out of the sperm plug at the right time. Before laying the annulus is covered with glair and possibly this may act to bring the sperms out as well as to protect them from the water, which produced marked and apparently destructive changes in the sperms. Some osmotic factor may here be concerned in bringing out the sperm. Other means of getting the sperm out from the waxy tube that we have called the sperm plug and from the interior of the annulus might be: the pressure that the sternal plate between the fifth legs may exert upon the annulus when the legs are forced forward, as sometimes seemed to be the case about the time of laying; or some activity of the small pleopods of the first abdominal somite. The former action, however, seems only to force the annulus to face more vertically in place of horizontally while the necessity of the first pleopods as instruments in fertilization was disproved by cutting them off from a female about to lay and finding that the eggs underwent normal cleavage as if fertilized.

In support of the view that the sperm issue from the annulus at the time of laying it was found that if the annulus was then removed the female seemed not to be inconvenienced, going through turning movements as usual, but the eggs did not develop. This may, however, have been due to the fact that the female was lifted out of the water, the glair disturbed and thus both eggs, and presumably sperm, exposed to the water, which may have prevented fertilization even if the sperm were upon the eggs.

No sperm were found upon the eggs nor upon the annulus: when sperm are taken from the male or from the annulus they undergo changes of form which might make them less

recognizable upon the egg and moreover the egg is 250 times as thick as the sperm and quite opaque.

The whole process of sperm and egg-meeting and union is much in need of elucidation.

Sperm. — While the pairing habits of *Cambarus* are more complex than those of *Astacus* the sperm cells are not as complex in form as those described for *Astacus* by Herrmann. In place of the many radiating arms he figures *C. affinis* has six, as a rule, but sometimes 5, 7 or 8. This is also true of *C. bartoni*. The remarkable bowl shaped vesicle of the crayfish sperm does not have as complex a shape in either of these American forms as it has in *Astacus*. The diameter of the body is $8\ \mu$ while the arms extend out four times that distance on every side so that the entire spread of arms is over $70\ \mu$; but only the refractive vesicle is conspicuous and its longest diameter is less than that of the body.

Period of development. — Attached to the pleopods and presumably fertilized the eggs go through the developmental changes that have been described for *Astacus* by Reichenbach and others. As these specimens of *C. affinis* were kept in confinement the times of various phenomena could be determined with some precision and in general the eggs of any female develop at about the same rate while the eggs of different females progress differently. Eggs laid near the end of March, 1894, and in 1900, hatched late in May: eggs laid April 11th, 1901, hatched the end of May. In 1903 eggs were laid from March 23d to April 15th; when the eggs were kept in water at $12\frac{1}{2}^{\circ}$ to 14° c some required eight full weeks to hatch; others in a warmer room where the water was not constantly running hatched in six weeks, and some in just five weeks. Most were hatching about May 18th and this was true also of eggs on the females taken April 20th and then in late cleavage or even embryonic stages; so that it seems probable that late in May is a natural time for hatching in the open where these crayfish were taken.

Cleavage. — The nuclear multiplications and migrations of "cleavage" take place but slowly in this heavily yolk laden egg. From sections it seems that the sperm and egg nuclei may

be not far from the surface 12 hours after the eggs are laid, while 24 hours after laying the cleavage nuclei are near the centre of the egg and only about ten in number.

There are only a few cleavage nuclei half way out to the surface 48 hours after laying, while 72 hours shows a large number of nuclei near the surface.

In the live eggs some of the cleavage phenomena may be seen with a pocket lens and are much as described by Herrick for *C. immunis*. At about 72 hours there are rounded areas scattered all over the egg, shimmering through the outer part of the egg; each is about $15\ \mu$ in diameter and some 30 of them may be seen upon any face of the egg. When such eggs are crushed under the microscope the dense, clear nuclear areas may be found amongst the yolk spherules and also long bundles of fibres connecting the chromatin bodies.

Eggs taken at earlier times from different females differed and also upon the same female. At about 48 hours a few clear areas might be seen in a group deep within the substance of the egg; some eggs showed 5 or 6, some 30-40, some none at all. Later there were similar areas nearer the surface but upon one side of the egg only. Soon these areas spread so that but part of the surface of the eggs failed to show them and finally they are all over the egg.

After the end of the 3d day the increase of these areas by division is plainly indicated by their shape. From 82 hours on to 7 days there are some hundreds of areas each about 150 to $300\ \mu$, some elliptical, others dumb-bell shaped and others in pairs of rounded areas $150\ \mu$ in each diameter. There is now a very striking appearance as of light beads floating above the dark background of the egg yolk. As the areas increase in number they become crowded till they finally touch one another and now in profile stand up as hillocks bounded by valleys and projecting into a space of some $100\ \mu$ that is formed between the egg and its case.

In late cleavage the color of the egg, which is olive or yellow green at first but varies much in different females, is now more dark sage green and this color with the clear space about the egg gives the entire mass of eggs upon the female a more

transparent look that enables one to pick out eggs of this period with ease. Under the lens the eggs present a very attractive appearance as the surface has come to be covered by polygonal cell outlines that form a neat mosaic. These cells at first about $200\ \mu$ in diameter and containing nuclear areas $100\ \mu$ in diameter become reduced to $50\ \mu$.

The eggs are often much flattened spheroids that readily revolve in their cases so as to keep one face upward. The cells flatten down and the eggs again seem smooth.

After this first week there is a period of apparently little change, nearly a second week in which the eggs turn dark brown and at first were thought to be dead. The surface cells no longer show, while the yolk is arranged in large polygonal areas about $150\ \mu$ in diameter and not quite in contact with one another. Reagents, however, show the very many small nuclei of the surface overlying these yolk pyramids.

Embryos. — But before the end of this second week the embryo is outlined somewhat as in Reichenbach's Stages A and B; that is in gastrula stages.

In the third week Nauplius stages like Stages F and G of Reichenbach were arrived at in from 18 to 28 days in different batches of eggs. Apparently in connection with the very large amount of yolk in these eggs the embryo is small, only $600\ \mu$ on an egg $2000\ \mu$.

About the 30th day the embryo had grown to a length of $1000\ \mu$ and was about stage H of Reichenbach, that is with some nine pairs of appendages. However one rapidly developing lot of eggs got to that stage in 21 days and hatched out at the same time as a lot of eggs laid two weeks before this rapid lot. Here a difference of temperature was present and may have caused this unusually rapid development. In these exceptional eggs about two days were spent in passing from stages G to H and nine days from H to J. Reichenbach's final stage K was reached 15 days after J and hatching followed in from one to two days.

In *C. affinis* we thus found that cleavage took up the first week, the beginning of an embryo the second week, to progress as far as the Nauplius the third week and more, to enlarge the

embryo over one half of the egg a fourth week and more and to perfect the embryo for hatching a fifth and sixth week or more. The whole egg development required from five to eight weeks in different sets of eggs under different temperature.

The heart-beat. — When the embryo has grown so large that it occupies half of the shell and the yolk is correspondingly reduced the beating of the heart is quite conspicuous, more than two weeks before the embryo hatches. Its beat is rapid and may be more than one hundred to the minute and there is the remarkable feature of periodic slowing down and even stoppage. In one embryo the heart beat about 150 times in a minute besides resting some ten seconds so that the rate was very great. There were generally five rests in a minute each of one, two or more seconds each and the intervals between rests were taken up with 26 to 36 beats.

Hatching. — The hatching of the eggs as seen in a watch glass with 2-A. took place as follows. The stiff, transparent case within which the embryo has developed splits open along the side next to the embryo's back as a leather ball might if filled with something that expanded. Before this there were seen some muscular movements within the embryo and now the region still containing yolk material was seen to jerk, the antennæ now and then contracted in jerks and the legs moved slightly. The back of the creature became more and more exposed to the water, I Fig. 8. The legs showed seeming spasms of contraction travelling along them and causing local shortenings. The back of the head-thorax and of the abdomen protruded more and more till only the ends of the body and the limbs remained within the shell, II Fig. 8. The larva thus comes into the world back first. In their development the legs and the abdomen have been formed beneath the thorax and bent forward parallel to it, II Fig. 8; but now the legs are straightened out and raised up more nearly at right angles to the thorax and the abdomen also is moved backward and this aids in pushing the larva out to the position shown in II Fig. 8.

These changes have taken some fifteen minutes and after about five minutes more there is a sudden straightening out of the

abdomen which throws the whole creature out into the water as a long straight larva hanging with only the tip of the abdomen left inside the shell, III Fig. 8. The limbs now free in the water kick about and at times the abdomen contracts and since its tip is fast within the shell the result is that the body is brought up near the shell again. The fastening of the abdomen within the shell is brought about by means of a larval skin which is fast to the shell on the one hand and to the

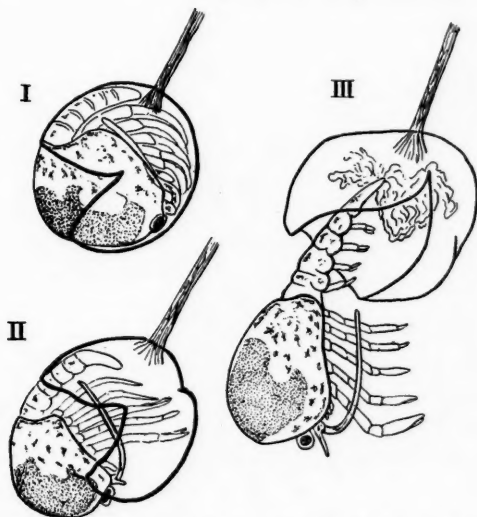


FIG. 8.—Three stages in the hatching of young. In III the larva remains attached by abdomen to cast off skin within egg shell. $\times 12$.

anal region of the larva on the other. This skin was seen at the beginning of hatching as a delicate veil over the eyes and doubtless some of the spasmodic contractions seen along the legs were serving to free the limbs from this embryonic skin. The larva thus moults and hatches at the same time and leaves its cast skin within the egg shell to be made use of as a means of keeping the larva from falling away from the mother, for a time. Hanging thus from the egg the young animal soon begins to spasmodically open and shut its large claws and when the body is brought up to the egg case by the contraction

of the abdomen, now and then, the claws finally clasp hold of the stalk of the egg case. As these big claws have the same larval character found in *Astacus*, that is recurved or hooked tips, they become firmly fixed in the material of the egg-string and apparently the larva could not get free again. The larva is thus made fast fore and aft, its claws are fast to the egg stalk and its anus is fast to the cast skin within the egg

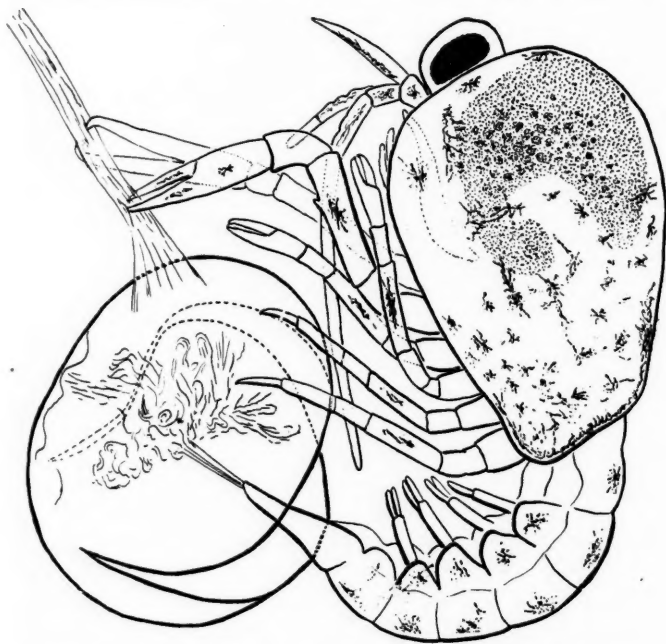


FIG. 9.—Larva 24 hrs. after hatching: claws fastened to stalk of egg shell and abdomen fastened to cast skin inside of egg shell. $\times 25$.

case. As the egg cases are still firmly tied to the pleopods by the strong egg stalks the larvæ live still pendent from and for protection dependent upon the mother.

Such a larva 24 hours after hatching is shown in Fig. 9, As in the European crayfish the young is hatched with a swollen globular head-thorax with proportions strikingly unlike those of the adult, but in life the head thorax is not so dispropor-

tionally swollen as it becomes in preserved specimens. In this region there is still a large, colored, saddle-shaped dorsal area where the yolk material is present.

All the appendages are present as in the adult except the first and last abdominal appendages so that the abdomen terminates with a very simple broad telson and has no wide tail fan. The eyes are very large. The second antennæ which were packed within the egg shell along the edges of the carapace external to the legs, I, II, III, Fig. 8, soon after hatching come to be between the legs right and left, Fig. 9, and in this dejected position add to the general helpless and incomplete appearance of the larva. The rostrum also aids in this infantile expression of the larva as it is very short and blunt and so bent down between the eyes that it cannot be seen except from a ventral view. Both antennæ and rostrum appear useless, or at least to be poorly placed or perfected to be of such uses as they seem to have in the adult.

This larva is so beautifully translucent that the grossly granular blood corpuscles may be seen projected rapidly along the blood spaces in the thorax, abdomen, legs and antennæ. These corpuscles have a long tail-like process behind and by this they often remain fixed till dragged loose into the current again. Scattered over the thorax and abdomen but not upon the telson are large, branching pigment cells of a crimson color and some are found also upon the antennules and antennæ, upon the fourth segments of the legs and upon the big claws as indicated in Fig. 9.

The creature remains fixed but moves its legs and this causes movements amongst the gills which may be seen through the carapace. There are also at times slight jerking movements of the abdominal appendages.

Respiration seems to be carried on very actively, for the very large scaphognathite may be seen through the carapace, as indicated in the above figure, bailing water out of the gill chamber at the rate of perhaps 180 per minute. The establishment of this rhythmic motion so characteristic of many Crustacea is here a slow process. Before hatching the only rhythmic motion seen was the beat of the heart, but after the creature had

emerged into the water this respiratory rhythm was gradually perfected. Two minutes after the larva had first straightened itself out in the water the scaphognathite was seen to swing back and forth but with some stops. Before that at the time of straightening of the body, there were only a few jerky contractions and then, after a minute or more, one or two swings. Five minutes after the body had straightened out in the water the scaphognathite was not in regular swing and even ten minutes was not long enough to acquire an uninterrupted, regular beat.

In some unobserved manner this first or preliminary larva frees its abdomen from the skin within the egg-case, but still remains holding fast by its claws. This larva is about 4 mm. long and lives this life of restricted freedom for only about 48 hours and then moults into a second stage.

Second larval stage.—As the first larva is attached only by its claws we would expect that when it moulted it would become loose and no longer connected with the parent, but such is not the case since it again possesses an anal fastening and later holds by its claws anew. When the moulting takes place the transparent skin of the larva breaks along the back and the back and head of the larva slowly push out through the rent. Then the antennules and antennæ are pulled out of the old skin and for the first time thrust forward into the permanent anterior position instead of being carried backward in the embryonic position retained in the first stage. The legs are pulled out of their old skins and kick about in the water; then the abdomen is bent free, all but the tip, where the anal region remains fast to that region of the cast skin and does not break loose even when it flaps vigorously. As the shed skin still has its claws fast locked in the egg stalk the larva though it has drawn its hands out of its gloves, as it were, and come out of its old clothes, still remains indirectly fastened to the mother since its telson is fast to its old suit and that is not broken but continuous with the gloves, or claw skins. At first the movements of the legs make the larva seem to be trying to crawl upon the cast skin but after a few minutes the large claws are opened and reaching about take hold of the shed or of the egg case. After many

minutes the claws get fastened to the egg stalk again so that the larva is a second time moored fore and aft; by the claws to the egg stalk and by the telson to the old shed which in turn is also fastened by its empty claw skins to the egg stalk. There are thus two real claws and two empty casts of claws fastened to the egg stalk close together. The new claws are still recurved at the tip but it did not appear that the larvæ were always so firmly fixed that they could not get away or at least be rather easily pulled off during the six days that this stage continues.

This moulting was found to take place also when the first larvæ were removed from the mother and kept 24 hours in running water so that the usual protection of the mother is not absolutely necessary for the future development.

The young in this second stage are about 4½ mm. long and have the form represented in Fig. 10. The head thorax is more elongated and crayfish-like in form. The rostrum though bent down between the eyes is much more prominent and when seen from above it has the characteristic lateral spines. The large eyes are prominently stalked. The antennules and antennæ which have some thirty segments, are carried out in front of the animal and moved about as if of use. The abdomen still ends in a bluntly rounded telson with no sixth pleopods as yet free, but these wide lateral appendages may be seen in bags or cases within the lateral part of the larval telson. The whole body is darkened by very numerous golden red pigment cells which are so crowded at the tips of the big claws that these are conspicuously crimson tipped. The yolk-colored area is reduced in extent and dorsally divided into separate right and left areas posterior to end of which is a large green area. On either side of the stomach a blue area adds to the complexity of the above region. The animal still remains somewhat translucent and blood corpuscles can be seen in places. In the antennæ the corpuscles pass from end to end, a distance of about 2 mm. in a few seconds. The legs bear conspicuous hairs not shown in the figure.

When these second larvæ are taken away from the mother they scramble over one another in heaps and do not walk alone, though if forced apart they can stand upon their legs and walk

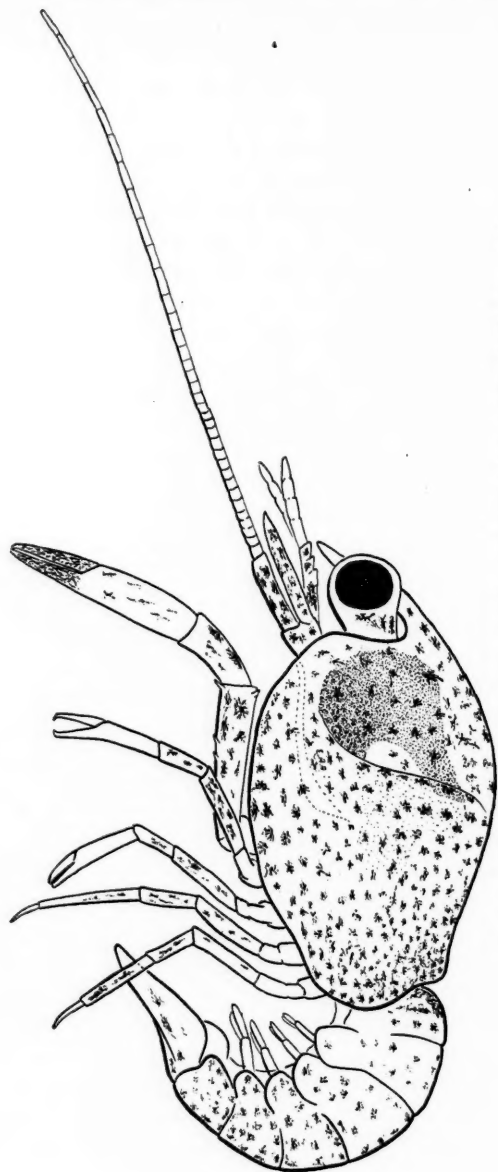


FIG. 10.—Second stage of larva: antennae now extended: attachment of larva to egg-stalks not shown. $\times 25$.

in a feeble manner. Those that hatched in McDonald jars and moulted to the second stage floated about attached to their sheds and to the moulded egg cases. When placed upon narrow strips of cloth they became entangled so that they could be hung up in the water away from sediment and with some such substitute for the maternal pleopods they could be artificially reared, if need be. Larvæ so suspended probably take food for they were seen to pass out long cylindrical greenish faecal masses 48 hours after moulting. These larvæ were seen to swim only when thrown into Perenyi's liquid when they darted backward with jerks of the abdomen much as do the adults. They live attached to the mother some six days in this second stage and during this time the yolk areas dwindle away to a large extent while the green areas remained and the blue areas stood out as conspicuous organs in the position of the "crabs eyes" on the sides of the stomach.

Third stage.—As seen in a watch glass the moulting of the larva from the second to the third stage takes but a few minutes. The head and thorax break out first, then the legs are pulled out, the abdomen flaps several times and is freed from the old skin entirely. There is now no anal connection of larva and shed and the free telson is found to have the sixth pleopods fully expanded by its sides so that a very wide tail fan is formed and its efficiency as a swimming organ is enhanced by very long plumose hairs. At length the larva has cut loose from its mother's apron strings. Yet it still remains upon the pleopods of its mother crawling about freely over the old sheds and egg cases. When removed from the mother these young walk about upon their long slender legs much like shrimp and when disturbed spring backward with widely expanded tail fan again suggesting shrimp.

These active third larvæ are 8 mm. long from tip of rostrum to end of telson, while the claws stretch out about 2 mm. in advance of the rostrum and the antennæ are 5 mm. long.

The head-thorax is most decidedly elongated and crayfish like. The eyes remain large and conspicuous and add to the shrimp like appearance. The antennæ still have exceedingly large exopodite scales. The rostrum is now straight out in front,

sharply pointed and of the characteristic gothic style of the adult.

The coloring of the larva has been altered by the addition of blue pigment cells over the carapace and legs. The tips of the big claws are no longer crimson but dark red owing to the fineness of the pigment reticulum there. The yolk coloring is gone but the long green hepato-pancreatic areas and the blue "crab's eye" regions show through the carapace.

When these young escape from their connection to the mother they leave behind upon her pleopods the old egg cases and stalks, and the first and second larval skins. These, however, all disappear before very long, but it was not observed whether the female removed them or whether the young may have taken part in tearing them off. The young continue to crawl about upon the pleopods for about a week and before the end of that time the pleopods are cleared of remnants of egg cases.

These free larvæ do not, however, remain continuously upon the mother but gradually make longer and wider excursions into the outer world, returning again and again to the mother. Three hours after moulting some larvæ were found walking about on the bottom of the aquarium and when disturbed they leaped backward several inches with great speed. When the female was lifted up all the young clung fast to the pleopods, but when she was left quiet a few minutes several of the young came off and walk about. The female gave no sign of knowing of the existence of the young but when she walked over a loose larva it turned upon its back, when touched by the pendent mass of young and quickly climbed up amongst the others. But attempts to make the young climb up on to bits of cloth or even shed skins held in a forceps were not successful.

In occasionally swinging the pleopods back and forth the mother was seen to wipe off against the bottom of the tank one of the great number of scrambling young that crowd the pleopods. Such a one at once turned over from its back on to its feet and walked, though it would appear that it probably had had no experience of horizontal surfaces.

The young that walk on the bottom of the aquarium do not

stay away long but return to the mother. Thus two days after moulting some 60 young were shaken loose from a female and scattered upon the floor of the aquarium, but in 20 minutes all but 12 were back again upon the mother's pleopods. Four days after moulting the young crawl all over the mother not only over the dorsal side of the abdomen but over the thorax and the head. As many as a hundred may be off at once walking about in the aquarium and climbing up into the chara plants while a little later only a dozen may be away from the mother. When no screen was used and the water ran strongly the young were carried away now and then and in such manner it may be that city reservoirs, such as those in Baltimore, get stocked with *C. affinis*. Eight days after moulting the young had all left the parents though sometimes a few went back to the maternal pleopods during the next few days. Thus by the fifth of June the young are most all self supporting and independent individuals with no other protection than that they find away from the parent.

How far there is any special recognition between the young and the mother was not determined; but when eight young were taken away from the parent and put in a dish with a female from which the annulus had been removed and which had finally lost all her dead eggs without hatching any they climbed up on to her abdomen and claws but soon got off again. The female did not act as did the real mother but moved about restlessly and wiped her mouth parts as if irritated by the young crawling over them. A few hours later there were no young upon her and four of them had disappeared. Again when several females were kept in the same tank there was some evidence that larvæ sometimes crawled up on to the wrong mother. Moreover in 1900 it was noticed that when a dead female was lifted from the water the young that dropped off returned again to crawl upon the dead crayfish and remained even when the parent was far advanced in decay. When the abdomen was broken open the young crawled upon the exposed muscles for a time but later were upon all parts of the abdomen except the broken surfaces.

Later stages.— By keeping the young of a single mother in a

tank by themselves some facts were made out as to the subsequent moultings during the rest of May, June and the first half of July. These young had a large aquarium with good supply of mud, Chara, anodons and various plants and insects with running water, sunshine and shallow water for good aëration. The young remained in the third stage for about 18 days and their color gradually changed from red to greenish owing to the great increase in the blue pigment. The legs also developed bands of dark color across them though otherwise almost invisible, yet the big claws stood out as reddish objects with blue at the base. The fourth stage had about the same coloring but being so much larger it was much more easily seen. The rostrum-telson length was 12 mm.: the claws reached out 2 mm. in advance of the rostrum: the antennæ were about 8 mm. long: the thorax was $2\frac{1}{2}$ mm. wide, and the tail-fan expanded $5\frac{1}{2}$ mm. One of these larvæ had short, simple papillæ upon the first abdominal segment to represent the pleopods, apparently of the female. These young were still translucent enough to show the beat of the heart, at a rate of about three beats to the second, and the circulation of blood corpuscles in the antennæ and legs, though the muscles were now much more conspicuous. The effect of the red pigment cells was everywhere toned down by the widely diffused blue cells.

In about 17 days, that is July 1st, many of the young had passed into a fifth stage. The length was now 15 to 18 mm., with the thorax about 3 mm. wide and the tail-fan 8 mm. The color of this fifth stage was white on the ventral side and elsewhere this was overcast by greenish. The legs were now white with dim transverse bands of gray while the large claws had lost the red and showed brilliant blue at the base of both finger and thumb.

The young move about actively, in walking they move the fore pairs of pleopods back and forth very rapidly. They swim readily and are still shrimp like in movement and in appearance, as they have long slender legs, protuberant eyes and wide tail-fans.

Within a week some larvæ were found in a sixth stage with a length of 21 mm., a thorax width of 5 mm., a tail-fan expanse of 11 mm. and antennæ about 19 mm. long.

Some eleven days later a very large larva was found with a length of 29 mm., a width of thorax of 7 mm., claws projecting 8 mm. beyond the rostrum, antennæ 25 mm. long and a tail-fan expanse of 14 mm. This creature was then a crawling crayfish with less tendency to keep high up amongst the water plants: it also was dark greenish, finely speckled, and there was blue on the legs. Little translucency was left and the animal looked much like a diminutive adult. The large claws were still marked with blue and had dark red at their tips.

This specimen was a male with two long, scroll-like pleopods carried forward in the groove under the thorax as in the adult and the following four pairs of pleopods were not modified: thus the male now has but one pair of modified pleopods as is the case in the lobster.

We may summarize the growth and moultings of the young of a single female during two months as follows. The eggs laid the night of March 28th, hatched into a first stage May 18th. With a length of 4 mm. they lived two days and moulted into a second stage. This second stage was $4\frac{1}{2}$ mm., long and lived six days from May 20th. The third stage was 8 mm. long and from May 26th lived 18 days. The fourth stage was 12 mm. long and from June 13th lasted 17 days. The 5th stage was 15-18 mm. long and lived from July 1st five days. The sixth stage was 21 mm. long and from July 6th, lived eleven days. The seventh stage was 29 mm. long, and from July 17th lived an undetermined time as observations were then discontinued. The first and second stages remained attached to the mother for about one week and were not more than $4\frac{1}{2}$ mm. long. The third stage, 8 mm. long, kept on or near the mother for about a week and then lived an independent existence for a week. The following stages were all independent and gradually took on all the adult proportions and colorings.

Growth of young crayfish.—The young were left in a tank with running water, mud, water plants, anodons and frequent feedings with raw hen's egg till October 6th. Then only eight survivors from a hundred or so were found. These were then measured and as seen in Table I they varied greatly in the amounts they had grown, though all were hatched from the eggs of the same mother.

Table I. Measurements of eight brothers and sisters 141 days after hatching.

TABLE I.

	1	2	3	4	5	6	7	8
Length: telson rostrum . . .	62	55	53	49	50	45	43	41
" chela	75	75	62	65	60	55	41?	47
" antenna	37	51	48	46	34	43	—	25
Width: thorax	15	15	14	13	12	11	11	10
" tail-fan	25	23	24	22	25	20	20	19
Sex	♀	♂	♂	♂	♀	♂	♂	♀
Length: anterior male organs .	9	9	9	9	8	8	7	7
" posterior " " . . .	10	10	10	10	9	9	7	7

Ten other young from various females hatched about the same date as the above and measured October 7th gave the following results, Table II.

TABLE II.

	1	2	3	4	5	6	7	8	9	10
Length: telson rostrum	60	59	52	52	45	39	40	33	30	22
" chela-telson	74	65	65	68	55	50	50	41	35	27
" antennae	45	30	47	46	25+	—	22+	—	20	16
Width: thorax	14	14	13	12	11	10	10	8	8	6
" tail-fan	26	25	23	24	20	20	19	16	15	10
Sex	♂	♀	♂	♂	♂	♂	♂	♂	♂	♀
Length: first male organs . . .	10	9	9	7	6	6	6	5	4	4
" second male organs . .	11	10	10	8	7	7	7	5	4	4

Taking the two tables together the largest crayfish was 62 mm. and the smallest 22 mm. long; the average length was 46 mm. During these two months and three weeks of summer some few seem not to have grown at all, while about one third of them have almost doubled their length. The great difference between the largest and smallest is but imperfectly represented by the above figures: thus the specimens, 10 of II and 1 of I, being in length as 31 to 11 seemed in bulk much more widely apart and in weight they were found to be as 13 to 7. Only 5 of the 18 were females but it is not known when this preponder-

ance of males arose, whether before or after hatching. The males have now two pairs of very conspicuous and well formed sexual pleopods of great size; the exterior pair are a little less and the posterior pair a little more than $\frac{1}{6}$ the length of the crayfish, but this ratio is the same in the adult. In these young males the antennæ often look longer and more tapering than in the females and that this may now be a secondary sexual character would seem to follow from the measurements. The eight males with perfect antennæ averaged 50.75 mm. in length and their antennæ were 42.875 mm., or 84% of the length of the body. The five females averaged 47 mm. in length and their antennæ 31.4 mm., or hardly 67% of the length of the body.

Under such conditions the young of *C. affinis* may then attain a length of two inches in their first summer. Additional data for knowing their rate of growth were obtained from some young hatched about June 1st, 1901, from eggs laid April 11. These young were kept in a large sink with running water, mud, water plants and anodons which dying from time to time probably gave them food material. The twenty survivors were measured February 11th, 1902, or $8\frac{1}{2}$ months after hatching and the lengths and widths as well as the sex are given in Table III. The sexes could be readily determined as the females had conspicuous annuli and the males well developed sexual pleopods.

TABLE III.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length	41	38	24	56	32	44	43	39	39	33	35	36	32	34	30	23	30	29	27	32
Width	10	9	6	14	7	11	10	10	9	8	8	9	7 $\frac{3}{4}$	8	7	5 $\frac{1}{2}$	7	6	6	7 $\frac{1}{2}$
Sex	—	♂	♂	♀	♀	♂	♀	♀	♀	♀	♀	♀	♂	♂	♂	♀	♀	♂	♂	♂

Number 4 may have been introduced by mistake: the others range in length from 44 to 23 mm. with an average of 34 mm. None are as long as two inches: one half are about 33 mm. and 80% above 29 mm. The sexes were about equally distributed, 10 males and 9 females.

These young did not attain to as large a size as those in the

preceding tables though they were four months older. But this additional time was autumn and winter and it would seem probable that the crayfish of Table III not being as well fed as the others had not grown quite as fast during the summer and had then remained stationary. Though they were kept in a warm room they were in running cold water.

The above twenty crayfish of table III were then kept in the same conditions during the rest of the Winter, Spring, Summer and Autumn and until December 5, 1903. The only two survivors were both females and at that time, being 18 months old, gave the following measurements. One was 70 mm. long and 16 mm. wide: the other 79 mm. long and 20 mm. wide. Since last measured, a space of ten months including a summer, each had *probably* doubled its length.

These two were left in the same surroundings, except when removed for breeding as below described, and measured again July 1st, 1903, when 25 months old. One was 79 mm. long and 20 wide, and the other 76 mm. long and 20 wide. The latter was clean and bright and the former dark and dirty as in winter so that we infer the smaller one had recently moulted and added 6 mm. or about $\frac{1}{2}$ to its length and $\frac{1}{4}$ to its width.

During their third summer these two females were kept with the young of Table I and thus had better food conditions. Only one survived till October 6th and then had a length of 90 mm. and a width of 24 mm., while its tail-fan expanded 43 mm. It had thus gained more than 10 and perhaps as much as 14 mm. in length or added $\frac{1}{3}$ to nearly $\frac{1}{2}$ to its length.

Summarizing the above data we see that the young of *C. affinis* reared in the above conditions of captivity hatch in May from eggs 2 mm. in diameter as larvæ 4 mm. long and there pass through stages of $4\frac{1}{2}$, 8, 12, 15-18, 21 and 29 mm. during the first two months. During the next three summer months they increase to an average length of 40 mm. but may grow as long as 62 mm. During their first winter they may, probably, not grow at all; but in the second summer they may reach a length of 70-80 mm. In the third summer the length may become 90 mm. as indicated by the sole survivor at 28 months.

That this crayfish grows in the open about at the rate above indicated seems not improbable from the measurements made upon 80 specimens of *C. affinis* taken early in October, 1903, from a small pond in Baltimore that had been stocked a few years before. Five of these were 85-100 mm. in length and obviously belonged to a different period of life as there were none between these and 65 mm. lengths. The remaining 75 ranged from 65 to 32 mm. There were only 6 below 40 and 12 above 56; the remaining 57 were from 40 to 56 mm. long. Thus 76% were from 40 to 56 mm. long and we may believe these were hatched that same Spring and were about 4 months old; the same would apply to the few smaller ones. The 12, or 16%, that were above 56 and not above 65 mm. long are too small for young that had passed a second summer and probably were of the same age as the majority. The five largest specimens were too large for second summer crayfish and probably were at the end of their third summer. The absence of any in what we would regard as second year lengths may be perhaps connected with the draining and drying that the pond suffered some winters.

Sexual maturity.—In rearing crayfish it was found that their sexual instincts and organs mature long before the maximum size was attained. Some of the young represented in Tables I and II were found to unite in pairs in October when but 4½ months, or 141 days old. These very small crayfish, two inches long, thus had their sexual instincts developed. Moreover the sperm taken from the male is then, apparently, just like that of the full grown males. The females 1 and 5 of the first table had sperm plugs, though the other females did not. These females were 62 and 50 mm. long. The female No. 2 of the second table was clasped by male No. 3 and subsequently had a sperm plug: this female was 52 mm. long. Whether these females of 50, 52 and 62 mm. in length will lay eggs next spring remains to be seen. The males seen to unite with females were 55 and 59 mm. long.

The two females described in the last section when 70 and 79 mm. long and 22 months old were put with males April 10, 1903. Though they had been alone for some months they at once were united with the males and the annulus of each

showed a sperm plug as it did not before. When they were 23 months old they both laid eggs.

Amongst the females that laid eggs in captivity there were both long specimens 120 mm. long and smaller ones down to even 75 mm. From their size we infer these small ones were about to begin their third summer. Thus though the sexual unions take place at the end of the first summer we have, as yet, no evidence of eggs being laid till the beginning of the third summer. However the autumnal union in the first year was found not only in the specimens reared in confinement but among those eighty above mentioned as taken in the open. And here it occurred both in the laboratory and in the pond and not only between the larger, third year sizes but between those of 56 mm. which, probably, were in their first year.

We see then that little specimens of *C. affinis* may have mature sexual instincts and unite in pairs in the autumn when they are but 4 months old and 50-60 mm. long, but as yet it is not known if they lay before they are 23 months old and 75 mm. long.

Finally.—In connection with the development of sexual maturity we may here refer again to the apparent sexual difference in lengths of antennæ noticed in connection with tables I and II. When the above 80 crayfish taken in the Autumn and thought to be most all of the first year, like those of the tables, were measured little difference between the lengths of the male and female antennæ was found. Throwing out the specimens with broken antennæ there were 37 males with an average length of antenna of 42 mm. and 36 females with an average length of antenna of 41 mm. Again the average male antenna was 81.3% the average length of the male body while the same for the female was 78.9%. The differences are so slight that, considering the errors in measurement, there seems here not enough evidence that the females have the shorter antennæ as a class.

BALTIMORE, November 5, 1903.

NATURAL HISTORY OF HAMINEA SOLITARIA SAY.

W. M. SMALLWOOD.

THE shell-bearing species of the family Bullidæ have been found freely distributed in the rocks since the Tertiary period. A large number of species have been found as fossils. Ludwig in Leunis *Synopsis der Thierkunde* states that there are between two and three hundred recent species. They have a wide distribution in both European and American waters, being commonly found in the sandy and muddy bays of the temperate regions.

The Bullidæ belong to the general order of Opisthobranchia and to the suborder Tectibranchia.

Thomas Say read before the Academy of Natural Sciences at Philadelphia on July 24th, 1821, a paper in which he gives "An account of some of the marine shells of the United States." In this article we have the first reference to *Bulla solitaria*. His description is as follows: "*Bulla solitaria*. Shell remarkably thin and fragile, pellucid, oval, narrowed at base, with numerous impressed, revolving lines, and transverse very obtuse wrinkles; apertures surpassing the tip of the shell; spire none, substituted by an umbilicus; umbilicus of the base none, less than half an inch. Inhabits the southern coast of the United States.

July 4th, 1835, J. G. Totten described a species of *Bulla*, variety *insculpta* which he dredged in about fifteen feet of water from the muddy bottom of the harbor at Newport, R. I. He maintains that *insculpta* is distinct from *solitaria* because of some slight variations in the color and shape of the shell. He says, "Thus (*insculpta*) can hardly be Say's *Bulla solitaria*. It is not umbilicated at the top as that species is; having merely a shallow pit in which nothing of the interior whorls can be seen. The *solitaria* is described as being narrowed at the base; but though our shell is regularly rounded in the passage, below, of

the right into the left margin, it is widely rounded; and the widest part of the shell is below the middle."

A. A. Gould, in his *Invertebrata of Massachusetts* ('41), considers *Bulla insculpta* and *Bulla solitaria* identical: he concludes his description of *Bulla insculpta* with the following paragraph:—
 "The differences between *solitaria* and *insculpta*, if there be any, must be very slight. Nor do I see that the two descriptions (Totten and Say) are at all inconsistent with each other. Still it is true that the shells from Martha's Vineyard are precisely like those from Charleston, S. C., and accord with Mr. Say's *solitaria*; and those from Roxbury are precisely like those found by Col. Totten at Newport, R. I., and described by him. The observable differences are, that the first are of a more dead white, are more cylindrical, the summit has a more square appearance, the revolving lines are less distinct, and there is always a perceptible opening in the region of the spire. These differences may be ascribed to age or locality."

Verrill ('73) describes *solitaria* as occurring along the Atlantic coast from Massachusetts Bay to South Carolina and makes no mention of *insculpta* except to assume that it is the same species as *solitaria*. The shells of *insculpta* and *solitaria* as figured by Totten, Gould, and Verrill seem to be identical.

The size of the shells which I have found at Wood's Holl, Mass., varies to a considerable degree; one shell found was only one-fourth as large as the average, the shape of a large number of shells which were examined varies in regard to the width and length of the lip. All of the shells examined were dextral. The distinctness of the revolving lines seems to depend on

the age, the larger ones being the more distinctly marked. The statement that the shells of *insculpta* seem to be more of a dead white color than that of *solitaria* is easily explained. The shell of the living animal is a golden gray; the golden tinge being given by the thin struc-



FIG. 1.—*Haminea solitaria* showing the proboscis and snout and tentacular disks. The parapodial folds conceal the anterior part of the shell and the mantle extends posterior to it. Natural size.

tureless membrane, the periostracum, which completely covers the shell (Fig. 1). When this membrane has suffered disinte-

gration the shell has the dead white color mentioned by Gould. In view of these variations I think that the shell as originally described by Say is identical with the *insculpta* of Totten and is the *solitaria* found in the vicinity of Woods Holl, Mass., and of Long Island, N. Y.

Pilsbry has decided to limit the family Bullidæ to the single genus *Bulla*. Formerly the members of the Akeridæ were included with the Bullidæ but the character of the radula, form of the shell, and relation of the animal to it enables one to sharply differentiate the two families.

The Bullidæ have in the radula a few longitudinal rows of teeth (formula I. 2. I. 2. I.). The animal is capable of complete retraction into the shell. There are no epipodal or parapodal lobes; the foot is long and tapering behind. The shell has a mottled color pattern.

The animal described by Say, Totten and others and referred to in this article is placed by Pilsbry¹ in the family Akeridæ and in the genus *Haminea*. "The Akeridæ are a much lower stock of Tectibranchs than Bullidæ, retaining the primitive multi-dentate radula, and the epipodal lobes, and having a thin, fragile unicolored shell.

The following is the specific description of *Haminea solitaria*: "Shell thin, subcylindrical, with gently convex sides, truncate vertex and rounded base; color horny or light brown. Surface shining, having irregular growth wrinkles and (under a lens) *fine, deeply impressed spiral grooves*, much narrower than their intervals, sometimes with smaller ones intercalated. Vertex white, somewhat impressed in the middle, subperforate. Lip arising to the right of the center, slightly thickened; outer lip gently arched forward. Columella thin, concave. Alt. 10, diam. 6½ mill" (Fig. 2).



FIG. 2.—The shell of *H. solitaria*. $\times 2$.

Habitat.—Until the report of Verrill, ('71-'72) nothing was said of the animal or its natural history. All writers confined themselves to a conchological description of the species. Verrill says that *solitaria*

¹ *Manual of Conchology*.

"is restricted to muddy shores and bottoms, in sheltered situations and is found also in muddy ponds and estuaries." Smith and Prime state that the animal is rare, found in mud at a depth of one or two fathoms. Balch ('99) states that the animal, "*Haminea solitaria*, *Bulla solitaria*, is rather uncommon alive, sometimes occurs on marsh grass, top of sea walls." In regard to the general distribution of this species Verrill says, "From Mass. Bay to South Carolina it is common in muddy lagoons and salt ponds, in shallow water where not too brackish, along the shores of Vineyard Sound, Buzzard's Bay, and Long Island Sound. Abundant in a small pond near Holme's Hole, in New Haven Harbor, in ditches near Fort Hale."

Haminea solitaria is found rather commonly in the Eel Pond and Big Harbor at Wood's Holl, at Hadley Harbor, and at the bathing beach on Buzzard's Bay at Wood's Holl. During the laying season the animal migrates into shallow water and may occasionally be seen upon the eel grass and algæ, but usually not in water less than two feet deep at low tide. If the eel grass be disturbed they drop at once into the water and fall to the bottom, where it is very difficult to see them, owing to their form and color being so similar to the ordinary weeds and mud at the bottom; thus it is practically impossible to gather animals by looking for them on the weeds or bottom. They have been secured in two ways: first, by taking an ordinary fine-mesh dip net and skimming off the sea weeds and half an inch of mud from the bottom, then carefully washing out the mud; in this way a number have been secured in the shallow ponds and lagoons about Wood's Holl; secondly, by dredging; this method is necessary in deep water. *Bulla* may be found, even in the breeding season, in water thirty feet deep in the Big Harbor at Wood's Holl, — the greatest depth where they have been found. This peculiarity may be due to the fact that their former laying spot in shallow water is now occupied by a deep sea wall. Dr. Charles B. Wilson obtained a number of *solitaria* by skimming in clear water near Edgartown about the 18th of August. He was sure that the net did not pass over any eel grass or sink beneath the surface. I feel sure that this is the real explanation of the occurrence of *Bulla* in great abundance

just before the egg-laying time, and their equally sudden disappearance after the egg-laying time. They simply rise to the surface and swim away.

In the summers of 1897 and 1898 most of the specimens obtained by me were collected in the larger of the two so-called "oyster ponds" near the Marine Biological Laboratory. Although a large number of capsules were taken from this place, over one hundred capsules were gathered from another locality and put into this lagoon in order to assure an abundance of material in succeeding seasons. In the summer of 1899 no capsules could be found in this lagoon, in the summer of 1900 three capsules were found here, but all of the eggs had died before reaching the twenty-cell stage; the tide flows freely into the lagoon thus keeping the water comparatively fresh. The drainage from the Marine Biological Laboratory flows into an adjacent lagoon and it is possible that the water seeping through may have some poisonous effect which kills the eggs and has destroyed or driven out the animals themselves.

The Bulla found on the sandy bathing beach at Buzzard's Bay occurs about half an inch below the surface of the sand; usually near the capsule, which is the only indication of the presence of the animal.

*General Morphology.*¹—It is not my purpose in this section to go into the details of the various systems of organs except in so far as they are directly related to the development of the egg; I purpose, however, to give a brief sketch of the general form of the animal.

Probably the most striking feature of this species is its color, which is a golden gray thickly mottled with dark brown and occasional orange spots; one might almost say that the gray background looks as though sprinkled with fine sand. The shell is translucent and slightly striated spirally; it is not at all glossy or shiny. One would hardly expect to find much of a shell in a tectibranch, but in *solitaria* the reduction of the shell

¹ For a full discussion of the Morphology of the family Haminea (Bullacea) see M. Vayssiere, Recherches Anatomique sur Les Mollusques de La Familles des Bullides *Ann. Sci. Nat.* Tome 9. 1879. R. Bergh, Bullacea. *Reisen in Archipel d. Philippinen*, pp. 211-312, 1901.

has only just begun. The most noticeable feature in this process is the fact that the shell is thin and fragile, so much so that it must be handled very carefully. The second feature is that in the mature animal the shell is not large enough to shelter the whole body in its contracted state. The shell certainly cannot afford particular protection against enemies, but when we remember where the animal lives and its habit of crawling along the mud and sand, we can readily see that it could have no better protection than its color. It imitates the color of the roots of eel grass most closely; at first sight I have often mistaken the detached fragments of these roots for *Haminea*.

The size of the animal depends largely upon age; the smallest shell measured was three mm. in width, and five mm. in length; the average size of the mature shell is 7 mm. in width, and 10 mm. in length. The average length of the extended animal including the shell is 2 cm.; the smallest animal was 8 mm. in length. I can make no definite statement as to the age or size at which *H. solitaria* begins to lay, but can say that I have never known the smaller ones to lay. In the aquaria the animals die after laying, but I do not believe that this fact can be used as proof that they always do.

The foot of *Haminea* possesses, though not clearly distinguished, the three divisions characteristic of the typical molluscan foot. From the mesopodium arise the parapodia; these are lateral lobes, or folds, like extrusions of the edges of the foot. In some of the Opisthobranchia the parapodia (epipodia of Pilsbry) are highly developed and unite upon the back, completely covering the shell. In our species however the parapodia cover only the anterior part of the shell.

The young animal moves by stretching forward the head and foot, and then drawing the visceral mass forward, so that the progress results from an alternate stretching and contraction of the anterior flexible part of the body. The posterior part being drawn ahead at each contraction. In the mature animals there is no such noticeable division in the movement; with them locomotion is apparently a continuous gliding process.

The anterior part of the animal terminates in a broad thin proboscoidal snout. Running back from the end of the snout

there are two tentacular disks, which are divided only part way. There is very little movement in these disks, except as they shift about over the anterior portion of the shell. In this species there seem to be no special sense organs in the tentacular disks. So far, I have been unable to explain their function. The tactile sense is usually located in the tentacles, but in our animal the anterior portion of the snout performs this function, as is very evident from its movements. In many of the *Opisthobranchia* the mantle folds over part of the shell, but in *H. solitaria* the only external evidence of the mantle is a thick fold which occupies the lip of the shell and extends back of it for about four mm., it is here extended and affords a surface equal in width to the shell. At first sight one would think because of this arrangement that the foot extended from the snout to the posterior portion of the animal, but closer inspection shows a sharp demarcation which indicates the boundary between the posterior portion of the meso-podium and the mantle. All of the parts of the body that are exposed are covered with columnar, ciliated epithelium. A great quantity of mucus is secreted by the animal, so that in crawling about the dish they often leave a nearly perfect tube of mucus. This is secreted by numerous typical single-celled glands, which are especially abundant at the edges and tip of the snout, and the outer portion of the tentacular disks.

The especial characters aside from the shell which distinguish *H. solitaria* are the stomach plates and the form of the radula.

There are three stomach plates so arranged that the food is triturated by them (Fig. 3). The plates are composed of chitin, having their bases firmly imbedded in the strong muscles of the stomach. The form of a single plate is shown by the camera drawings (Figs. 4, 5). The portion of the plate that comes in contact with the food is differentiated into a number of ridges which are larger and more pronounced at the anterior end. The

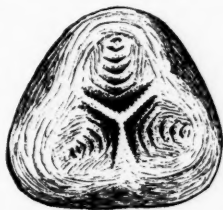


FIG. 3.—Showing the arrangement of the stomach plates, each of which is imbedded in a large amount of muscle. The free surfaces are so arranged as to triturate perfectly the food.

largest teeth are found on the anterior part of the plate, having



FIG. 4.—One of the chitinous stomach plates as seen from the free surface. $\times 24$.



FIG. 5.—One of the chitinous stomach plates as it appears from a profile view. $\times 24$.

a triangular form. The size and prominence of the teeth gradually decreases toward the posterior part of the plate. This gradual increase in size of the teeth and the ridges indicates how both are continually forming to take the place of the more anterior ones as they become worn out. The youngest teeth are those found on the smallest ridges. In some instances it is difficult to be certain that teeth are even present.

The radula is an interesting structure but one that is difficult to represent in a drawing. When this organ is removed from the animal, it is somewhat triangular in shape (Fig. 6). In the center of the anterior part there is a single row of teeth, having

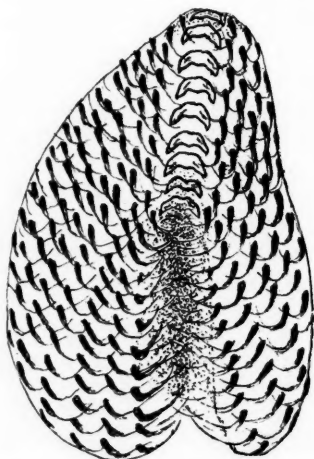


FIG. 6.—The radula seen as a transparent object. The anterior end is uppermost in the drawing. The formula is infinity. one. infinity. $\times 72$.

a broad free margin and terminating at each side in a rather broad blunt process (Fig. 7). There are an indefinite number of long, slender, sharp teeth arranged in rows which correspond to the teeth of the median ridge. The bases of these lateral teeth are imbedded in the muscles of the radula (Fig. 8). Each lateral tooth is bent at an angle of about 90 degrees. This arrangement of the teeth would give the following formula for *H. solitaria* ∞ . I ∞ .

The genital organs.—This system of organs is fully discussed by Lang; I have been able to demonstrate of all the

parts as given by him and will, therefore, quote freely from his description. The Opisthobranchia are all hermaphrodites. Haminea is no exception to the general rule and comes under the first type as described by Lang. The germinal gland consists of numerous "converging diverticula." The eggs and spermatozoa arise from the same part of the gland and are intermingled. During their development they become detached and lie free in the cavity of the gland. The ducts of *H. solitaria* are considerably complicated, because of the development of the accessory organs. The ovotestis lies between the lobes of the liver and the posterior part of the body; this gland has numerous branches, which finally collect into the common hermaphroditic duct; the duct empties into the common genital cloaca. The genital aperture opens



FIG. 7.—Three of the median plates from the radula. $\times 390$.

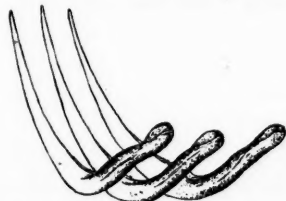


FIG. 8.—Three of the lateral teeth from the radula. $\times 390$.

into the extreme right anterior part of the mantle cavity, and from it there is, continued forward, an open ciliated furrow, which carries the spermatozoa to a gland called the "prostate"; this opens into the penis. "The penis itself lies in the right, on the boundary between the head and foot. When it is at rest its sheath lies in the cephalic cavity near the buccal mass." Two important glands open into the genital cloaca by a common duct; first, the albumen gland, which is comparatively small and lies upon the surface of a second, known as the nidamental gland; the latter is much larger than the former and yields the outer protective envelope of the egg. The albumen gland supplies the albumen for the egg capsule.

The "receptaculum seminis" is connected by a short duct with the genital cloaca and receives the spermatozoa at the time of copulation. Of course the size of this vesicle varies according to the season and according to whether or not it is full of spermatozoa.

Breeding habits.—In general the breeding season of our species extends from the last of June to the first of September. There seems to be considerable variation in the time when the egg laying begins, in 1897 the capsules were first found July 9th. In 1898 none were found until July 25th. Then three were found which had been laid within thirty-six hours. In 1900 collecting was begun July 10th and capsules were found which must have been laid as early as June 25th, judging from the fact that the embryos had already left some of the capsules and were leaving others. However, the animals lay most abundantly between July 15th and August 15th. The egg capsules may be found scattered through the eel grass and algæ on the edges of the pond, or lagoon, but each capsule is attached to grass or algæ from two to six feet below the surface of the water. Apparently the animals congregate in favorable spots to lay their eggs. In one place in the eel pond, where the water is about three feet deep at low tide, over five hundred capsules were collected in ten days within an area about ten feet square. During the same period repeated trips were made to various parts of the pond, but only a very few capsules were found.

On the sandy bathing beach previously mentioned the animals lay in the same place from year to year. Here there is a small patch of eel grass in about three feet of water; in and around this patch the eggs are laid in great numbers. In this locality the capsules are attached either to the eel grass or, as in most cases, simply to the sand. The sandy bottom slopes out gradually for about one-fourth of a mile, merging finally into a muddy bottom. I have never dredged here, either before or after the breeding season, so I do not know where *Haminea* stays during other seasons; but I have dug down into the sand, both before and after the laying season, and have never been able to find any of the animals. It is difficult to ascertain where *Haminea* lives at other times than the breeding season, but the fact that it cannot be found in shallow water except at this time seems to show that it migrates into deeper water. This idea is also supported by the occurrence of *Haminea* in thirty feet of water in the Big Harbor, and by the statement of Verrill ('72) to the effect that, "A specimen of winter flounder

(*Pseudopleuronectes americanus*) caught at Wood's Holl in August, contained a large number of the shells of *Bulla solitaria*." The winter flounder is dredged in the vicinity of Wood's Holl at a depth of about fifteen to thirty feet, and is mentioned by Verrill as devouring *Bulla* in large numbers. *Haminea* has been dredged in May in Hadley Harbor at a depth of twenty-five feet. These facts would tend to show that its natural habitat for the most of the year is the deeper water. A further proof that *H. solitaria* lives in deep water except during the breeding season is supplied by the following facts: August 28, 1900, Dr. C. V. Wilson while skimming the surface water with a fine mesh net near Edgartown, secured a large number of *H. solitaria*. They all died during the first night although they were placed in a small aquarium. The time that these individuals were collected was after the usual egg laying periods, for the forms that live in the vicinity of Wood's Holl. When taken, they were evidently migrating into the deep water. The observations of Verrill and those of Wilson seem to show conclusively that *H. solitaria* is a deep sea dweller except for about six weeks, when it takes up temporary quarters in some favorable place in shallow water.

During the first two summers that *H. solitaria* was under my observation I was unable to discover any evidences of copulation, owing to the fact that early in the season I did not have in the laboratory any considerable number of animals; but in the summer of 1900 I had in the laboratory about forty animals at one time and was able to make observations on copulation. The habit which these molluscs have of crawling over one another and of collecting into a pile, concealed the fact and method of copulation for a long time. One day, however, I noticed two animals apparently copulating, the genital grooves were slightly extended and came together, from one the penis protruded into the genital groove of the other. The animal receiving the penis laid a mass of eggs eight hours after the copulation, the other one did not lay. In a second case of copulation the animal laid after the lapse of thirty-six hours, but this was an unusually long time and probably due to the unnatural conditions surrounding it. In the time that elapses between the period of copulation and deposition, *H. solitaria* is similar to many of the nudibranchs (Smallwood :03).

The question arose as to whether or not copulation took place after laying; in the three cases that I was able to observe copulation did take place after one of the animals had laid but I was unable to observe it between animals both of whom had already laid. Fresh *Haminea* were collected, put into separate dishes, and kept there for three days; during this period they did not lay; then specimens which had copulated and laid were put in with these, copulation followed in each case in about an hour and the animals laid in about twelve hours. Sections of the ovotestis before and after copulation prove the correctness of the above observations.

In copulation the animals do not uniformly assume any definite position in regard to each other. The genital groove opens on the right side just anterior to the lateral fold of the parapodium, thus obviating the necessity for an exact position. Copulation continues for about fifteen minutes.

This species lays a single gelatinous mass (Fig. 9) which is spherical, about three-quarters of an inch in diameter. Its contents are chiefly composed of albumen, which is secreted by the albumen gland. As soon as the albumen comes in contact with the water it swells by the rapid absorption of water, and thus affords a gelatinous protection for the egg. When the eggs first leave the genital groove they are in strings; in a few hours the strings lose their continuity and the eggs are scattered throughout the egg mass.



FIG. 9.—The eggs of *H. solitaria* are laid in a gelatinous mass, spherical in form, and attached to some foreign object. The drawing is natural size.

would be very difficult to count the eggs in a single mass. The size of the capsule varies considerably; as a rule those found on the eel-grass are about a third less in diameter than those laid on the bottom. The egg masses laid in the laboratory were often irregular in shape and much smaller than those collected from the pond. The specimens in confinement that laid small and irregular masses, often laid a second time without a second copulation. It takes from 40 to 50 minutes for an animal to lay a complete normal egg mass.

The living egg of *H. solitaria* is so small and so richly supplied with deutoplasm that satisfactory observations on the segmentation are impossible except in the early stages. The egg is spherical, enclosed within a thin structureless membrane. The size of the egg varies, the average is about .08 mm., being smaller than the eggs of *Umbrella* (Heymons, 93), *Crepidula* (Conklin, '97), *Nucula* (Drew, :01) and that of most molluscs that have been studied.

Before segmentation the polar differentiation of the egg is but slightly indicated, the yolk being almost uniformly distributed except in the region of the polar bodies. It has already been

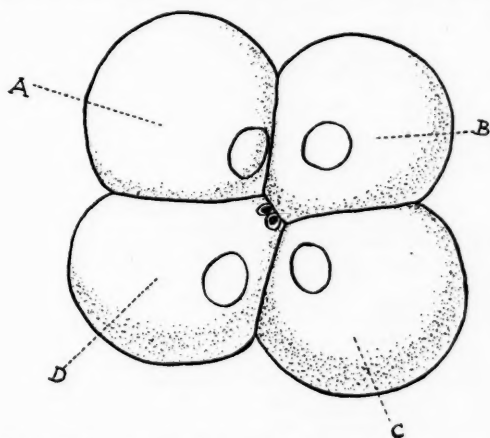


FIG. 10.—The four celled stage which shows the relation between the four blastomeres characteristic of Mollusca. $\times 275$.

stated that it takes forty minutes for the animal to lay a mass of eggs. Within ten or fifteen minutes after each egg is laid the first polar body appears at the animal pole and thirty minutes later the second polar body can be seen. It happens occasionally that the first polar body is very large and may even contain yolk spheres.

The egg segments into two cells a half hour after the second polar body has appeared. In about thirty per cent. of the eggs observed, the first division of the egg did not divide it into two equal blastomeres, one being noticeably larger, a variation which

is similar to Umbrella (Heymons '93). Within thirty or forty minutes after the formation of the two celled stage, the four

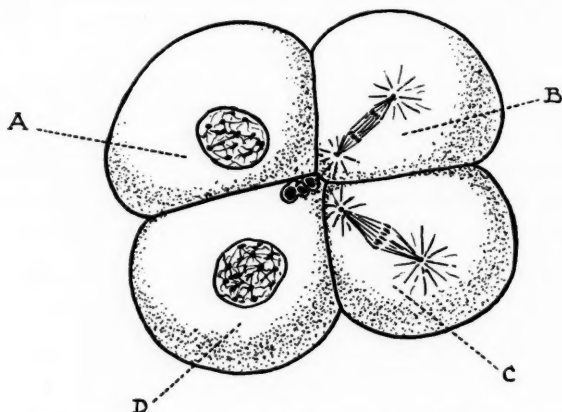


FIG. 11.—The four-celled stage preparatory to the formation of the first quartette of micromeres. $\times 275$.

celled stage is formed. Just prior to the formation of the four celled stage, the spindles do not lie parallel which is an agreement with other molluscs and indicates a spiral division¹ (Fig. 10).

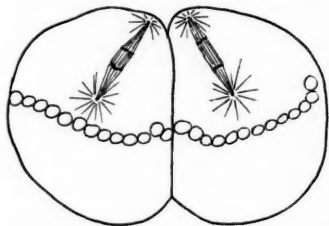


FIG. 12.—A section of the four celled stage passing into the eight celled stage to illustrate the position of the spindles when the micromeres are formed. $\times 140$.

After not more than thirty minutes, the third cleavage separates the egg into two conspicuous parts, the protoplasmic micromeres and the deutoplasmic macromeres. These micromeres are considerably larger in comparison

with the size of the macromeres than in many molluscs. The same is true for the two following quartettes of micromeres

¹ For a complete discussion of the method and significance of segmentation in Mollusca see Mark, E. L., Maturation, Fecundation, and Segmentation of *Limax campestris*. *Bull. Mus. Comp. Zool.* vol. 7, 1881. Conklin, E. G., The Embryology of *Crepidula*. *Jour. Morph.* vol. 13, 1897. Holmes, S. J., The early development of *Planorbis*. *Jour. Morph.* vol. 16, 1900.

which results in the complete envelopment of the macromeres at an early stage. The third cleavage is dextrotropic (Figs. 11, 12, 13, 14).

The time that intervenes between the formation of the second and third quartettes of micromeres is the same as that for the second and third cleavage. From this time on it was impracticable to follow the further cleavage stages on the living egg. Stained preparations confirmed the observations made on the living egg.

The second quartette of micromeres is formed by the fourth cleavage which takes place in an anti-clockwise direction, the

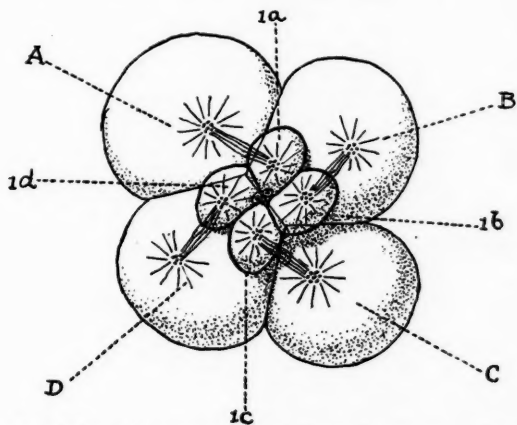


FIG. 13.—The telophase in the formation of the first quartette of micromeres. The movement is dextrotropic.

cells taking a position alternating with the cells of the first quartette (Fig. 15). The next cells to undergo segmentation are the first micromeres formed, segmentation takes place in a læotropic direction giving rise to the turret (trochoblast) cells (Figs. 15, 16); immediately after, indications of division in the second quartette of micromeres and the macromeres are evident. The egg sketched shows eight complete spindles in the metaphase. The spindles occurring in the macromeres participate in the formation of the last quartette of micromeres, the movement being in a right handed spiral. Soon after the above described

changes have taken place the macromere which is designated by the letter D divides independently of the three other macromeres into two cells of unequal size but both containing yolk spheres. The smaller cell is concerned in giving rise to the mesoblastic bands and is entirely covered above by the micromeres.

It can be seen from the brief description of the early segmentation stages and the accompanying sketches that *Haminea solitaria* does not exhibit any segmentation phenomena other than those characteristic of mollusca. The subsequent cleavage

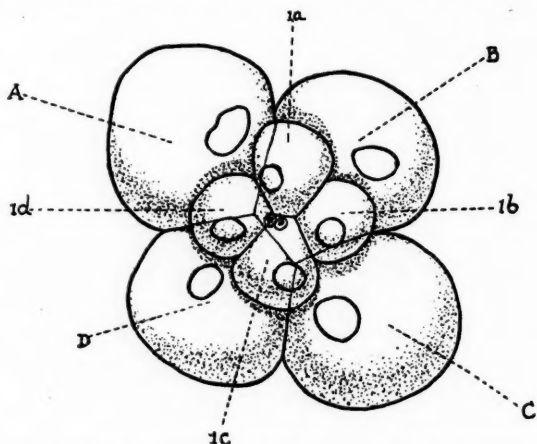


FIG. 14.—The eight celled stage fully formed showing the position of the micromeres above the furrows of the macromeres. $\times 275$.

stages have been followed sufficiently to indicate that they are in agreement with related forms that have been described heretofore.

The embryo usually begins to move in the egg capsule at the end of the seventh day; the cilia on the mantle border are well differentiated and can be seen in motion. It is difficult to ascertain the exact length of time the embryo remains in the egg capsule but I have known it to continue there for a week. In most of the egg masses that have been under observation the embryos have died before becoming free swimming individuals although some were immediately placed in aquaria or in the

eel pond in bottles closed with several thicknesses of cheese cloth. In placing the embryos in their natural environment, it was hoped that it would be possible to determine the changes taking place between the embryo and the adult. Although repeated experiments were made in various parts of the eel pond, no satisfactory results were obtained and I am unable to state how the transition from the embryo to the adult takes place.

During the summer of 1899 a number of pressure experiments were tried for the purpose of determining the effect on segmentation and the subsequent history of the embryo. The fact that the eggs are surrounded by a great mass of albuminous

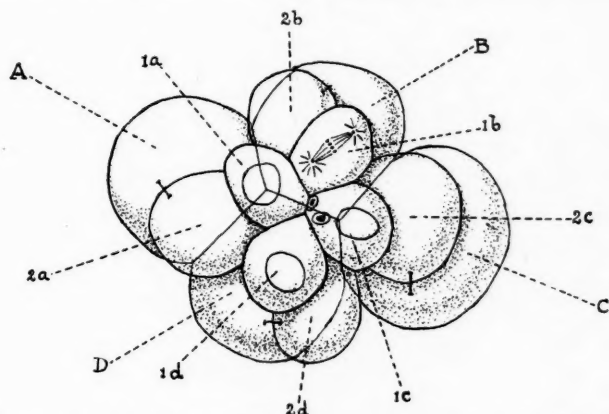


FIG. 15.—The twelve celled stage. The second quartette of micromeres was formed by a laetotropic movement. One cell, 1b, is undergoing segmentation which will result in the formation of a turret cell. $\times 275$.

material made it easy to apply light pressure. A small number of eggs were placed on a slide and covered by a second slide, the amount of pressure was regulated by passing a small rubber band around the slides. The eggs were taken in the one celled stage after the polar bodies had formed; they were left under pressure two hours and the changes which took place during the period were carefully noted. I took pains to see that all of the eggs were forced to segment in an irregular manner. After the pressure was removed the eggs were placed in the aquarium in a bottle which was stoppered with cheese cloth. Although a

number of experiments of this kind were tried with different degrees of pressure I was not able to get any normal embryos. A few abnormal embryos were reared but they lived but a few days. It hardly seems that it will be possible to get any fruitful results from pressure experiments on the eggs of *H. solitaria* for these further reasons: eggs in the egg masses broken during collection develop abnormally, probably because the sea water gains access to them; eggs laid in imperfect egg masses in the laboratory frequently develop abnormally; occasionally I have

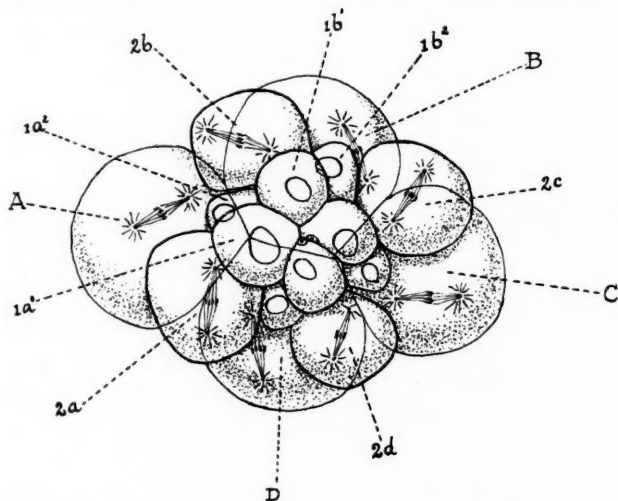


FIG. 16.—The sixteen celled stage. The first quartette of micromeres have given rise to four turret cells, $1b^2$. The third quartette of micromeres is forming by a dextrotropic movement. The second quartette of micromeres is the process of division. $\times 275$.

collected what appeared to be perfect egg masses and found that the segmentation was very irregular, keeping these eggs under observation, I found that they invariably died in a short time; some apparently normal egg masses have been found to contain eggs in all stages of segmentation from the one celled to the thirty celled stage.

In brief then to summarize: The Tectibranch mollusc, first described by Say, and subsequently by Totten, Verrill, and others, should, according to Pilsbry, properly be regarded as *Haminea solitaria*. The dental formula is $\infty. 1 \infty$. The egg

laying period extends from the middle of June to the last of August during which time the adults migrate from the deep water into shallow ponds and lagoons. The eggs are laid in a gelatinous mass, spherical in form, attached to eel grass, algæ, stones, sticks, etc. The eggs pass from the one celled stage to the free swimming embryo in seven days. The method of segmentation of *Haminea solitaria* is in close agreement with the other mollusca. No positive results were obtained from attempts to produce abnormal segmentation.

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November 15, 1903.

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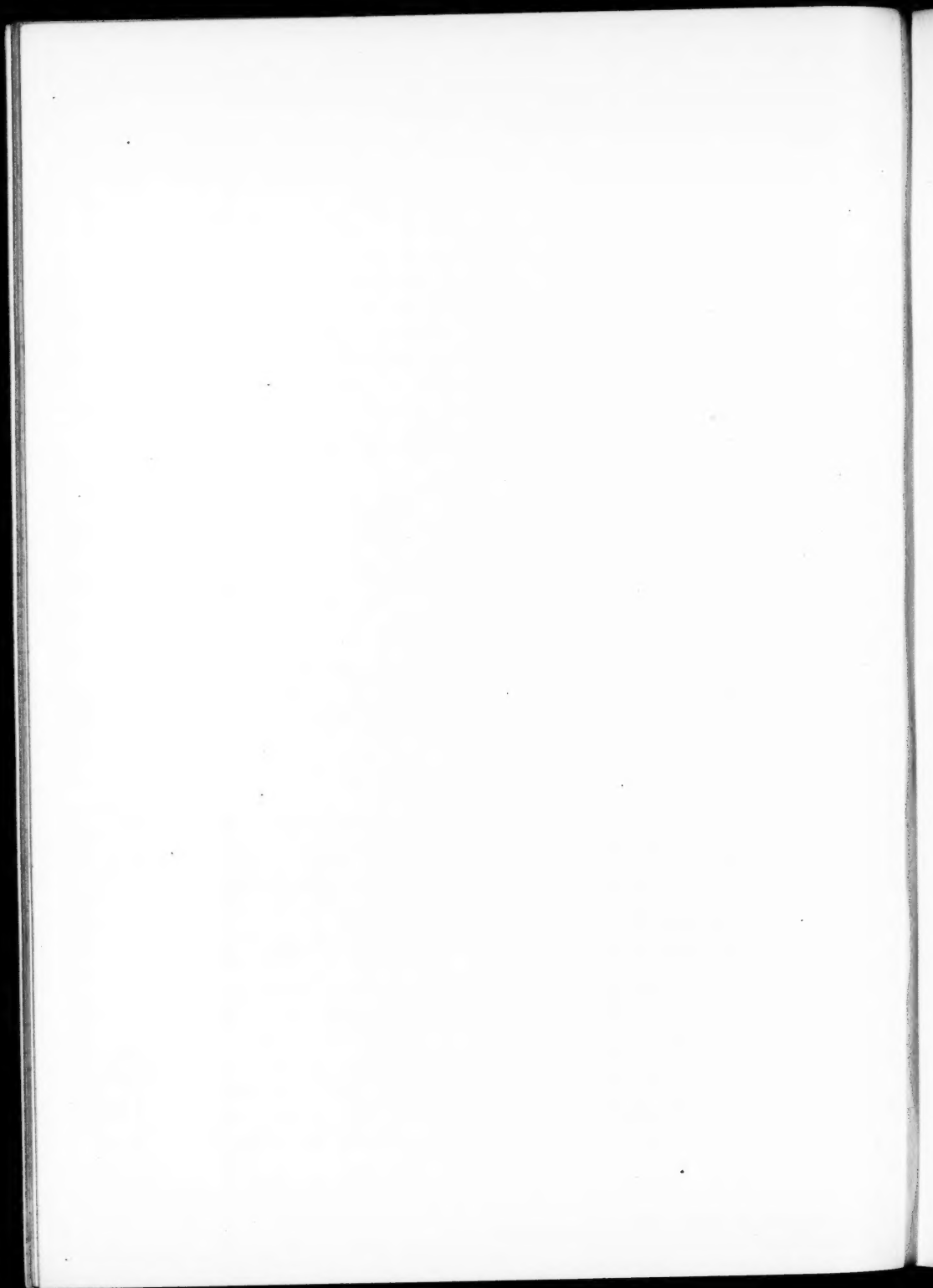
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NOTES AND LITERATURE.

GENERAL BIOLOGY.

Mendelism and Cytology.¹—Guyer's doctor's thesis written in 1900 but printed and distributed in the latter half of 1903 is remarkable for its "anticipation" of Mendel's law of purity of the germ cells, the outcome, unlike Mendel's results, of a cytological study. He first describes the course of spermatogenesis in normal pigeons. The spermatogonia (the ancestral sperm cells immediately preceding the reduction stages) contain 16 chromosomes which are split in the cell division that forms the primary spermatocyte. As the primary spermatocyte grows, synapsis, or a fusion of the chromosomes in pairs, occurs; and this Guyer interprets as the conjugation of maternal and paternal chromosomes. Eight thick rings are formed which break equatorially in the division by which the secondary spermatocytes are produced. When the secondary spermatocytes divide to form the young spermatozoa only four chromosomes are to be seen. These chromosomes Guyer regards as quadrivalent and he suggests that "reduction" takes place when they divide.

He suggests that the reduction division of the four-fold chromosomes may be in any plane and so varying combinations of maternal and paternal qualities will go to each spermatozoon. Thus it might happen that in the division the maternal and paternal qualities were segregated (and this he regards as the prevalent result in hybrids); or it might happen that some of both the maternal and paternal chromatin went to each spermatozoon. The "purpose" of the formation of the quadrivalent chromosomes is to give greater variability.

In respect to hybrid pigeons, Guyer notes that the offspring of the common brown ring dove mated with a white ring dove are brown. The offspring of these brown hybrids are either white or brown and the latter color predominates. The author says (p. 36): "This points to the conclusion that in the brown birds we may have

¹ Guyer, Michael F. *Spermatogenesis of Normal and of Hybrid Pigeons*. A. Dissertation, etc. University of Chicago, Chicago; 1900. 61 pp., 2 (double) plates. [Distributed (and printed?) 1903.]

both intermediate forms like the hybrids of the second generation and forms which have reverted to the brown grandparent, as the white doves have seemingly returned to the white grandparent." Here we have a clear recognition of what Mendel calls dominance! Also, this, (p. 48): "If a spermatozoön and an egg containing characteristics of the same species unite, then the reversion will be to that of the species; if a sperm cell containing the characteristics of one species happens to unite with an ovum containing characteristics of the other species, then the offspring will be of the mixed type again. By the law of probability the latter will be the more prevalent occurrence, because there are four combinations possible, and two of the four would result in the production of mixed offspring, while only one combination could result in a return to one of the ancestral species." Here we have even the quantitative part of Mendel's law expressed in 1900!

The foregoing Mendelian generalizations are suggested by the behavior of the hybrid germ cells in the spermatogenic stages. The mitoses are frequently abnormal — two spindles lying side by side, owing to the fact that the chromosomes are segregated in different parts of the cell. This segregation suggests an incompatibility between the chromosomes of the two species — and it results in "pure" germ cells — with the parental qualities segregated.

Finally, the all too brief chapter of suggestions will repay careful study. It is regrettable that so notable a contribution to the mechanism of heredity should have been so long delayed in appearing.

C. B. D.

Inheritance of Acquired Mental Characteristics.¹ — A Chicago solicitor of patents has written a book on heredity that is bold and in many respects crude, but which presents so many facts that it warrants respectful consideration. The subject is the control of the intellectual quality of the offspring by the intellectual activity of the parents. The thesis is that the descendants of intellectually active parents inherit the latter's activity so that, within limits, the more active during a given time the parents have been, or the longer the time of their activity, the more intellectually active the offspring, the greater their chance of achieving eminence. It is nothing new, of course, that the offspring of intellectual or successfully active people are especially apt to have eminent progeny, but it is rather new to

¹Redfield, C. L. *Control of Heredity. A Study of the Genesis of Evolution and Degeneracy.* Chicago, A. C. Clark, 1903. 8vo. 343 pp., illustrated.

be told that of the progeny of such eminent people the younger sons are more likely to be eminent than the older sons; or conversely, that eminent men, in general, particularly when not sons of eminent men are sons of old men.

To prove the thesis stated in the last paragraph it would be necessary first of all to find the average age a large random sample of mothers and of fathers of a given race and time at the birth of all their children and then to show that eminent people (using as a measure of eminence some arbitrary standard such as the average number of lines in the biographical descriptions in a number of encyclopedias) were born of parents clearly older than the average of parents of that race and time. But even this would not be wholly satisfactory. It would be better to compare the average eminence of the earlier and the later born of pairs of brothers. If the average eminence of the later born brothers exceeded that of the earlier born by several times the probable error then the greater chance of eminence of younger sons could be said to be demonstrated. But even if the younger sons showed a clearly greater eminence, still we could not assert that this greater eminence was due to inheritance of acquired intellectual activity of the parents rather than to the possible superior training of later sons.¹ Now Mr. Redfield has not treated his statistics of eminence in relation to birth rank with sufficient care; he is convinced of the truth of his theory; and he uses all of the art of a skillful lawyer to prove it.

Mr. Redfield got a standard average age of Caucasian parents in general from the Redfield genealogy, which indicates that 50% of children are born from fathers under 33 years and mothers under 29 — these ages are taken as his standard although he thinks them a trifle high for Caucasians in general. He compares with this standard the father's age of eminent men at the time of the latter's birth, gleaned his facts from encyclopedias, and finds many cases of sons of old men. He devotes one chapter to "The Hall of Fame" men. He finds among these many cases of exceedingly old parentage. For instance when Franklin was born his father was 51; and the total interval in three generations is $51 + 57 + 70 = 178$ years. On the other hand the average birth rank of Eli Whitney's male ancestors was 30 and for 25 Hall of Fame men the median paternal birth rank is 35.5 years, not much above Redfield's standard.

¹To avoid the possible influence of superior training of younger children records of trotting horses or milk-cattle would be superior to records of men. Mr. Redfield thinks his theory confirmed in trotting horses.

The argument is weakened by including the birth ranks of Joseph, Moses, David and Solomon! We have little reliable information concerning the ages of the ancestors of these men. Also, our confidence in Mr. Redfield's critical ability is terribly shaken by his comparison of maternal impressions to mimicry, and by his attempting to account for the intellectual inferiority of the lower animals solely on the ground of their shorter generations.

Despite, however, all the crudities of the book we cannot deny that it contains suggestions and that many of the conclusions cannot, in our present state of knowledge, be refuted. The work should incite to further and more careful investigation to confirm or refute Mr. Redfield's theory, or, rather, to see if statistical evidence supports the hypothesis of the inheritance of acquired dynamical qualities.

C. B. D.

BOTANY.

Notes.— Lieforing 29–30 of Ascherson and Gräbner's *Synopsis der mitteleuropäischen Flora* deals with Cyperaceæ, Araceæ and Palmæ, — among the latter characterizing American and other foreign species that are hardy in cultivation.

No. 26 of the new series of "Contributions from the Gray Herbarium of Harvard University," forming Vol. 39, No. 11, of the *Proceedings of the American Academy of Arts and Sciences*, is a revision of the genus *Flaveria*, by J. R. Johnston.

Under the title *Arkiv för Botanik*, a new serial has been launched by the K. Svenska Vetenskaps-Akademie. Several of the papers of the opening number are of interest to American botanists.

After a long interval, parts 3 and 4 of *Muhlenbergia* has appeared, and contain descriptions of a number of western phanerogams by Heller and Congdon.

The supplement to the *Index Kewensis*, in fascicle 3, reaches Physaria.

The embryology, etc., of *Sequoia sempervirens* are discussed by Lawson in *Annals of Botany* for January, which also contains a historical account of the structure and morphology of ovules, by Worsdell.

"The Flow of Maple Sap" is the subject of *Bulletin No. 103* of the Vermont Agricultural Experiment Station.

The influence of lime on plant growth is discussed by Wheeler and Adams in *Bulletin 96* of the Rhode Island Agricultural Experiment Station.

Vol. 4, no. 3 of the *West Indian Bulletin* is devoted to cotton.

The extent of variability in Eucalyptus is considered by Maiden in Vol. 36 of the *Journal and Proceedings of the Royal Society of New South Wales*.

A systematic-anatomical study of the leaf in Acer, with special reference to the late elements, by Warsow, has been issued from the Fischer press, of Jena.

An anatomico-biological thesis on seeds of Podalyriæ, by Lindinger, has been issued from the Fischer press, of Jena.

An interesting thesis on the anatomy and biology of the fruit and seed of certain aquatics, by Fauth, has been issued from the Fischer press, of Jena.

The principal species of wood and their characteristic properties are described by Snow in an illustrated volume recently issued from the press of John Wiley and Sons of New York.

An illustrated account of Persian dates and their introduction into America, by Fairchild, forms *Bulletin No. 54* of the Bureau of Plant Industry of the U. S. Department of Agriculture.

Germinating spores in a fossil fern sporangium are described by Scott in *The New Phytologist* of January 27.

A preliminary notice on fertilization, alternation of generations and general cytology of Uredineæ is published by Blackman in *The New Phytologist* of January 27.

New or unrecorded Australian fungi are being published by McAlpine in the current *Proceedings of the Linnean Society of New South Wales*.

An article on the genus Harpochytrium in the United States, by Atkinson, is published in the *Annales Mycologici*, for November.

A paper on Italian Hypogaeæ, by Mattiolo is separately issued by the *Accademia Reale delle Scienze di Torino*.

Bulletin 21 of the Boston Mycological Club is devoted to *Agaricus subrufescens*.

Accounts are given, in the January *Journal of the New York Botanical Garden*, of the laboratories of the institution, including that in Jamaica, and of the Carnegie desert laboratory at Tucson.

A well illustrated account of the Desert Botanical Laboratory of the Carnegie Institution, and of the desert regions of the Southwest, by Coville and MacDougal, constitutes *Publication No. 6* of the Institution.

A note in the *Journal of the Kew Guild* for 1903, shows that in 1902 1,323,376 persons visited the famous botanical gardens at Kew, the average for each of the previous ten years being 1,355,503.

Ramírez, in *Anales del Instituto Médico nacional*, vol. 6, no. 2, publishes notes on some of the manuscript icones of Sessé and Mociño.

"The Book of Herbs," by Lady Rosalind Northcote (John Lane, London and New York, 1903), is a tasty and interesting little book, well illustrated, and with a portrait of Parkinson for frontispiece.

Those who care for old books will find interest in a supplementary catalogue of the Sturtevant Prelinnean Library of the Missouri Botanical Garden, by Hutchings, published in the 14th *Report* of that institution.

An account of the botanical work that has been done in the Philippines, with a bibliography, is given by Merrill in *Bulletin no. 4*, of the Bureau of Agriculture of the islands.

The third part of vol. 2 of Wood's "Natal Plants," devoted to grasses, and the first part of vol. 4 of the same work, containing gamopetalæ, have recently been issued.

A popular Sketch of Hawaiian botany, by Morrison, is contained in *Floral Life* for November.

Some views of the vegetation of the Dismal Swamp accompany an article on the proposed ship canal through it, in *The American Inventor* of December 1.

Dr. Holm contributes some Notes on Canadian Species of *Viola* to *The Ottawa Naturalist*, for December.

Perrot and Guérin publish an account of the *Didiereas* of Madagascar, with habit illustrations, in the *Journal de Botanique* of August–September.

A critical revision of *Gossypium*, by Aliotta, has been separately printed from vol. 5 of the *Annali della R. Scuola Sup. d'Agricoltura in Portici*.

Andean cacti of interest are being described by Schumann in current numbers of the *Monatsschrift für Kakteenkunde*.

The Indian Species of *Polygonum* and reviewed by Gage in vol. 2, no. 5, of the *Records of the Botanical Survey of India*, dated Sept. 14.

Part XX of Holm's Studies in the Cyperaceæ is contained in *The American Journal of Science* for December.

The comparative anatomy and phylogeny of *Sequoia* are discussed by Jeffrey in vol. 5, no. 10, of the *Memoirs of the Boston Society of Natural History*, issued in November.

A new *Alstonia*, yielding rubber, is described from New Caledonia by Schlechter in *Der Tropenpflanzer*, for November.

Shade trees, etc., adapted to New Mexico are considered by García in *Bulletin no. 47* of the Agricultural Experiment Station of New Mexico.

An article on Conservation and Cultivation of Medicinal Plants, by Krämer, is contained in the December number of the *American Journal of Pharmacy*.

An account of the grape-growing industry of the United States is contained in *The National Geographic Magazine*, for December.

Symbiosis of *Volvox* and *Azotobacter* is discussed by Reinke in the *Berichte der deutschen botanischen Gesellschaft*, vol. 21, Heft 8.

A discussion of soil temperatures and vegetation by MacDougal, is reprinted from the *Monthly Weather Review*, for August.

School Science, for December, contains a description of a new and cheap form of Auxanometer, by Lloyd.

An account of a seemingly bacterial disease of tobacco, by Stevens and Sackett, is given in *Bulletin no. 188* of the North Carolina Agricultural Experiment Station.

Some oddly grown trees are figured by Newcomb in *Floral Life*, for December.

President Seward's address before the Botanical Section of the British Association, at its recent meeting, is printed in *Nature* of October 8, and deals with the composition and distribution of the floras of the past, with reference to the corresponding phases of the flora of to-day.

Harshberger contributes to part 2 of the current volume of *Proceedings of the Academy of Natural Sciences of Philadelphia* a paper on Mutations of *Hibiscus Moscheutos* and one on Form and Structure of the Mycodomatia of *Myrica cerifera*.

A spontaneous rapid vibratory movement of certain shoots of Eucalyptus is recorded by Tavares in *Broteria* of October 30, — which contains a number of other articles of botanical interest.

The propagation of plants is discussed by Corbett in *Farmers' Bulletin No. 157*, of the U. S. Department of Agriculture.

Data on autumnal coloring, as correlated with leaf deterioration, are contributed by Keegan to *Nature* of Nov. 12.

Anatomical studies of Potamogeton are applied to the classification of the species of this difficult genus by Raunkiaer in a paper reprinted from Heft 3 of the current volume of *Botanisk Tidsskrift*.

An article by Fritsch on the Use of Anatomical Characters for Systematic Purposes is contained in *The New Phytologist* for October.

Fendlera rupicola is illustrated in *Curtis's Botanical Magazine* for November.

Ostenfeld and Raunkiaer, in Heft 3 of the current volume of *Botanisk Tidsskrift*, show that Hieracium, like Taraxacum, appears to be apogamic,—a peculiarity not shared by other genera of Cichoriaceæ experimented on.

The distinctive marks of *Catalpa speciosa* are figured and described by the Editor in *Arboriculture* for October.

A paper on *Asplenium Ruta-muraria*, by Christ, in *Hedwigia* of October 7, includes an analysis of North American forms.

Numbers of Lloyd's *Mycological Notes* published during the current year include studies of *Catastoma*, *Mitremyces*, *Tylostoma*, *Secotium*, etc., accompanied by a good many photograms.

A third supplementary list of the parasitic fungi of Wisconsin, by Davis, has been printed in advance from Vol. 14 of the *Transactions of the Wisconsin Academy*. A total of 661 species is now recorded.

Fascicle 4 of Sydow's *Monographia Uredinearum* carries *Puccinia* to species No. 1094.

A paper by Holden and Harper, on nuclear division and fusion in *Coleosporium*, is separately printed from Vol. 14, part I, of the *Transactions of the Wisconsin Academy*.

Taphria (or *Taphrina*) *cærulescens* forms the subject of *Bulletin No. 126* of the Alabama Experiment Station, by Wilcox.

Part 9 of Koorders and Valeton's *Additamenta ad Cognitionem Floræ Arboræ Javanicæ*, forms No. 61 of the *Mededeelingen uit 's Lands Plantentuin*, published by Kolff of Batavia.

A primer of forestry, by Pinchot, constitutes *Farmer's Bulletin No. 173*, of the U. S. Department of Agriculture.

A popular account of broom corn, *Sorghum vulgare*, by Hartley, forms *Farmers' Bulletin No. 174*, of the U. S. Department of Agriculture.

A reprint of Schöpfung's "*Materia Medica Americana*" (1787) constitutes *Bulletin No. 6* (Reproduction Series No. 3) of the *Lloyd Library*.

Palaequium Suffianum, a new Gutta-Percha plant of New Guinea, is described and figured by Schlechter in *Der Tropenpflanzer* for October.

A popular illustrated account of the pulque and mescal Agaves of Mexico is published by Dodge in the *Scientific American* of September 19.

The Journals.—*American Journal of Pharmacy*, January:—Lloyd, History of *Echinacea angustifolia*; Schneider, Gardens of Medicinal Plants.

The Botanical Gazette, December:—Transeau, On the Geographic Distribution and Ecological Relation of the Bog Plant Societies of Northern North America; Berry, *Aralia* in American

Paleobotany; Ganong, Vegetation of the Bay of Fundy Salt and Diked Marshes (concluded); Eastwood, Notes on *Garrya* with Descriptions of New Species and Key; Bergen, Transpiration of *Spartium junceum* and other Xerophytic Shrubs; and Atkinson, *Geaster leptospermus* — a correction.

Botanical Gazette, January: — Wylie, Morphology of *Elodea canadensis*; Newcombe and Rhodes, Chemotropism of Roots; Weld, Botanical Survey of the Huron River Valley — II, A Peat Bog and Morainal Lake; Godding, Southwestern Plants; Coker, Selected Notes — III.; and Farmer, On the Interpretation of the Quadripolar Spindle in the Hepaticæ.

The Bryologist, January: — Harris, Lichens—*Peltigera*; Miller, *Pogonatum urnigerum*; Grout, Notes on Vermont Mosses; Holzinger, The Genus *Hymenostomum* in North America; and E. G. Britton, *Papillaria nigrescens*.

Bulletin of the Torrey Botanical Club, January: — Arthur, New Species of Uredineæ, Harper, Explorations in the Coastal Plain of Georgia during the Season of 1902; Murrill, The Polyporaceæ of North America — VI, The Genus *Polyporus*; Robinson, the Spines of *Fouquieria*.

Journal of Mycology, December: — Morgan, A New Species of *Berlesiella*; Whetzel, New Method of Mounting Superficial Fungi; Bates, *Puccinia Phragmitis* in Nebraska; Stevens, Poisoning by *Lepiota Morgani*; Ellis and Everhart, New Species of Fungi; Kellerman, Uredineous Infection Experiments in 1903, Minor Mycological Notes — II, and Notes from Mycological Literature — VII. A portrait of Atkinson forms the frontispiece.

Journal of the New York Botanical Garden, January: — Britton, The Tropical Station at Cinchona, Jamaica; MacDougal, Research Work in the Garden; and The Desert Botanical Laboratory of the Carnegie Institution.

The Ohio Naturalist, January: — Kellerman and Jennings, Report for 1902 on the State Herbarium, including Additions to the State Plant List; Schaffner, Poisonous and other Injurious Plants of Ohio (concluded).

The Plant World, December: — Baum, The Breadfruit — III; Safford, Extracts from the Note-Book of a Naturalist on the Island of Guam — XIII; Simpson, Effects on Vegetation of the Hurricane

in Florida; Crawford, Some interesting Plants formerly abundant near Germantown, Pa.; and Thompson, Boniato — a Tree or a Yam?

The Plant World, January: — Safford, Extracts from the Note-Book of a Naturalist on the Island of Guam — XIV; Roosevelt, Our Forest Policy; Tullsen, Notes from Pine Ridge Agency, S. Dak.; Dobbins, The Parsleys; Barrett, Correction and Comment; and Gorman, Oregon Wild Flowers in Need of Protection.

Rhodora, December: — Fernald, Pursh's Report of Dryas from New Hampshire; Ames, *Lobelia* \times *syphilitico-cardinalis*; Collins, *Woodsia glabella* in Maine; Robinson, Records of *Wolffia* in Mass.; Rand, *Matricaria discoidea* in N. H.; Chamberlain, New Stations for Maine Plants; Pease, Trisetum in Andover, Mass.; Freeman, *Lycopodium selago* on Mt. Holyoke; Osmun, *Cuscuta trifolia* in Mass.; Harger, New Station for *Phaseolus perennis*; and Collins, On Corallorhiza and Taraxacum.

Rhodora, January: — Fernald, Two Allies of *Salix lucida*; Brainerd, Notes on New England Violets; Rehder, Pseudo-monoclinism of *Chionanthus virginica*; Wiegand, Some Notes on Galium; Seymour, A Newly Introduced Galium; and Hervey, Plants new to the Flora of New Bedford.

Torreya, December: — Britton, Cornelius Van Brunt (with portrait); Cavers, Explosive Discharge of Antherozoid in Hepaticæ; Earle, Key to the North American Species of *Inocybe* — II; Maxon, A Fern New to the United States; and Holm, Linnæus' Work on Ferns.

Torreya, January: — Stone, Physiological Appliances — I; Banker, Observations on *Phallus ravenelii*; Canby, Joseph Hinson Mellichamp; Berry, Primary Venation in Cinnamomum.

The Transactions of the American Microscopical Society, Vol. 24, contains the following articles of botanical interest: — Bessey, Evolution in Microscopic Plants; Hollis, Two Growths of *Chlamydomonas* in Ct.; Seawell, Method of Concentrating Plankton without Net or Filter; and Bessey, Structure and Classification of the Phycomycetes, with a Revision of the Families and a Rearrangement of the North American Genera.

The American Botanist, of September, contains the following: — Bailey, The Defences of Plants; Bradshaw, Collecting Seeds;

Saunders, Poison Ivy and its Extermination; Buchheister, Variations in the Common Polypody; Gilbert, The Jewel Weeds; and part 6 of the Editor's Botany for Beginners.

The Botanical Gazette for October contains the following articles: — Harshberger, An Ecological Study of the Flora of Mountainous North Carolina; Parish, Sketch of the Flora of Southern California (concluded); Ganong, Vegetation of the Bay of Fundy Salt and Diked Marshes, An Ecological study (continued); Atkinson, A New species of Geaster; Davis, Tilletia in the Capsule of Bryophytes; and Lyon, Two Megasporeangia in Selaginella.

The Botanical Gazette, for November, contains the following: — Evans, *Odontschisma Macounii* and its North American Allies; Ganong, Vegetation of the Bay of Fundy Salt and Diked Marshes; Harshberger, An Ecologic Study of the Flora of Mountainous North Carolina (concluded); Moore, Mitoses in the Spore Mother-cell of Pallavicinia; and Haug, Is Detmer's Experiment to show the Need of Light in Starch-making reliable?

Volume 10 of the *Proceedings of the Iowa Academy of Sciences* contains the following botanical articles: — Pammel, Ecological Notes on the Vegetation of the Uintah Mountains; Weems and Hess, Chemical Composition of Nuts used as Food; and Fitzpatrick, The Scrophulariaceæ of Iowa.

The *Proceedings* of the second meeting of the *Iowa Park and Forestry Association*, recently distributed, contain a number of articles of botanical interest.

The *Journal of the New York Botanical Garden*, for November, contains the following: — Britton, Report on Cuban Exploration; Lloyd, Report of a Botanical Expedition to the Island of Dominica; and Nash, Report on Exploration in Hayti.

A new publication, "Leaflets of Botanical Observation and Criticism," has been launched by Professor E. L. Greene. The first signature is dated Nov. 24, 1903.

The Plant World, for November, contains the following: — MacDougal, Some Aspects of Desert Vegetation; Safford, Extracts from the Note-Book of a Naturalist on the Island of Guam — XII; Barrett, A Forgotten Fruit; and Waters, Field Notes.

Rhodora for October contains the following articles: — Robinson, Insecticides used at the Gray Herbarium; Fernald, A new *Kobresia* in the Aroostook Valley; Cushman, Notes on New England Desmids

— II; Wentworth, Two Plants new to the Flora of Lynn, Mass.; Woolson, New Station for *Asplenium ebeneum* *Hortoniae*; B. M. Britton, A New England Station for *Buxbaumia indusiata*; Rand, Galinsoga in Maine; and A Leaflet of the Seal Harbor Village Improvement Society.

Part 3 of *Trees and Shrubs*, issued Nov. 14, adds still further to the number of American species of Crataegus.

The Bulletin of the Torrey Botanical Club for October contains the following articles:—Cannon, Studies in Plant Hybrids—The Spermatogenesis of Hybrid Peas; and Evans, Hepaticæ of Puerto Rico—III.

The Bryologist, for November, contains the following:—Britton, The Splachnums; Holzinger, On Some Fossil Mosses; Grant, Some Moss Societies; Miller, *Buxbaumia aphylla*; and Clarke, Mounting Mosses.

In addition to an important paper on Crassulaceæ, by Britton and Rose, vol. 3, no. 9, of the *Bulletin of the New York Botanical Garden* contains a paper by Berry on the Flora of the Matawan Formation, one by Williams on Bolivian Mosses, and one by Zeleny on the Dimensional Relations of the Members of Compound Leaves.

The Bulletin of the Torrey Botanical Club, for December, contains the following articles:—Griggs, On Some Species of Heliconia; Underwood, Summary of our Present Knowledge of the Ferns of the Philippines; and Kupfer, Anatomy and Physiology of *Baccharis genistelloides*.

The Fern Bulletin, for October, contains the following articles:—Gilbert, The Fern Flora of New York; Clute, Fernwort Notes—IV; House, Scolopendrium from Canada; Eaton, The Genus Equisetum in North America—XV; Clute, The Species-conception among the Ternate Botrychiums; and Druery, New Forms of Ferns. A portrait of Mr. Maxon forms the frontispiece to the number.

Part II of the botanical portion of the *International Catalogue of Scientific Literature* has been issued under date of November, 1903. It is of nearly double the size of the first part (626 pages), and is essentially on the same lines as the earlier part.

The Journal of Mycology, for October, contains the following articles:—Morgan, Some Western Specimens; Morgan, Note on *Corticium leucothrix*; I. Kellerman, The Accentuation of Mycological

Compound Names; Ellis and Everhart, New Species of Fungi from Various Localities; Kellerman, Minor Mycological Notes — I; Ohio Fungi, Fascicle VIII [descriptions and annotations]; Index to North American Mycology (continued); and Notes from Mycological Literature — VI.

The *Journal of the Royal Horticultural Society*, for October, contains a number of botanically interesting articles.

The fourteenth *Report of the Missouri Botanical Garden*, in addition to the customary administrative reports, contains a Supplementary Catalogue of the prelinnean library of the Garden, and a revision of the genus *Lonicera*, by Rehder.

Rhodora, for November, contains the following: — Ames, Hybrids in *Spiranthes* and *Habenaria*; Leavitt, Reversionary Stages in *Drosera intermedia*; Waters, *Asplenium ebenium proliferum*; Eaton, Notes on *Botrychium tenebrosus*; Deane, *Gaylussacia* in New Hampshire — a Correction; and Eaton, New Varieties of *Isoetes*.

Torreyia, for October, contains the following: — Underwood, The Early Writers on Ferns and their Collections — I, Linnæus; Howe, Note on the "Flowering" of the Lakes in the Adirondacks; and MacKenzie, A New Genus of North American Umbelliferae [*Pseudotænidia*].

Torreyia, for November, contains the following articles: Wootton, Ferns of the Organ Mountains; House, Notes on the Flora of Oneida Lake and Vicinity; Earle, Key to the North American Species of *Inocybe* — I; Berry, A Question for Morphologists; Stone, *Arisæma pusillum* in Pennsylvania and New Jersey; and Nash, A New Bamboo from Cuba.

CORRESPONDENCE.

To the Editor of the American Naturalist:

SIR:—In a suggestive article in the *American Naturalist* for August (XXXVII, 551–555), on “Vernacular names of animals,” Dr. Edwin W. Doran remarks, “I believe that I am the first who has thought it necessary to prepare a synonymy of the vernacular names of animals” and announces that “the author has in preparation a synonymy of all the vernacular names of vertebrates.” It is evident from this, and from interviews had with other naturalists, that a great work on the subject published more than a century ago is unknown to most who are especially interested in its subject-matter. Indeed, I have found that none of the naturalists of Washington whom I had asked knew about it, so completely has it been forgotten. Nevertheless, it is a work in four large quarto volumes of about 2400 pages with 4783 numbered columns and some additional leaves (preliminary) as noted below. I give the title of the work and analysis of the volumes.

General title.

Allgemeines | Polyglotten-Lexicon | der | Naturgeschichte | von
| Philip Andreas | Nemnich, J. U. L. | *mut. mut.* See below. | Zu
finden | Hamburg, bey Licentiat Nemnich | [etc.]

The title page of the first part is printed from a plate; those of the other parts from regular type. They are paged for or were bound in four volumes as follows:—

I.

[Erste Lieferung. A—Canus.] Eng. title page + 8 p. l. + col. 1–840. 1793.

Zweyte Lieferung. | — | Cap. — Fus. | title page + col. 841–1684.
1793.

II.

Dritte Lieferung. | G—N. | title page + col. 1-740. 1794.

Virete Lieferung. | O—Z. | title page + col. 741-1592. 1795.

III.

Fünfte Lieferung. | — | 1) Deutsches Wörterbuch der Naturgeschichte. | 2) Englisches Wörterbuch der Naturgeschichte. | title page + col. 1-676 (= Fünfte Lief. Deutsches W.) + col. 677-1056 (= Sechste Lief.). [No date.]

IV.

Siebente Lieferung. | — | 1) Französiches Wörterbuch der Naturgeschichte | 2) Italienisches Wörterbuch der Naturgeschichte. | title page + col. 1057-1376 (= Französisches W.) + col. 1377-1507 (= Italienisches W.) [No date.]

Achte und letzte Lieferung. | — | 1) Spanisches Wörterbuch der Naturgeschichte. | 2) Holländisches Wörterbuch der Naturgeschichte. | 3) Schwedisches Wörterbuch der Naturgeschichte. | 4) Dänisches, Norwegisches und Islandisches Wörterbuch der Naturgeschichte. | 5) Einige Nachträge. | title page + col. 1509-2108. 1798.

This bibliographical description will suffice to give some idea of the nature and extent of the work. It is only necessary to add that in the first 2 volumes, under each Linnæan genus, alphabetically arranged, the species are enumerated under their Latin names in alphabetical order and the vernacular names in different languages added under the Latin ones. Thus, under *Anas boschas domestica*, as "*Engl.*" 12 names applied to the subspecies as a whole in English as well as Gaelic, Welsh and Cornish, 3 of the drake, and 3 of the young are given; under *Anas boschas fera* 4 names are given as "*Engl.*"

It cannot be claimed that the English part is well done but the author at least "thought it necessary to prepare a synonymy of the vernacular names of animals" and carried the idea into execution in a very voluminous work.

Another noteworthy work carrying out the same idea for certain North American birds is Gurdon Trumbull's volume on "Names and Portraits of Birds which interest gunners," published in 1888.

Numerous minor contributions to the same subject have been published.

THEO. GILL.

(No. 446 was mailed April 28, 1904).

